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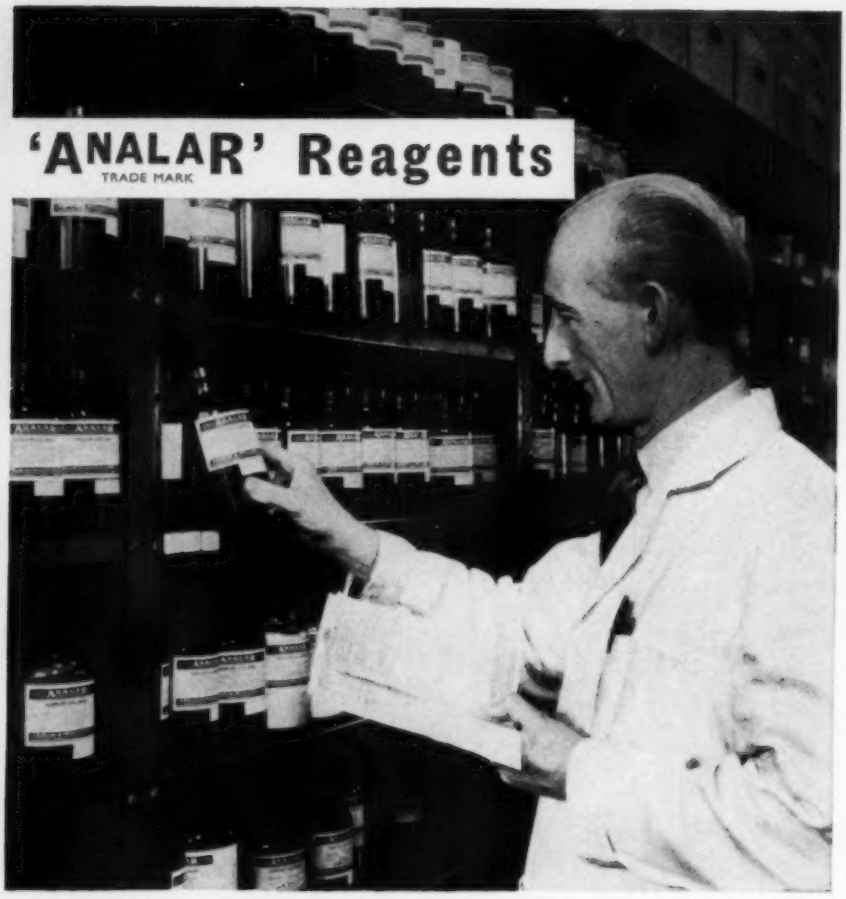

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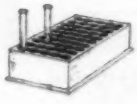

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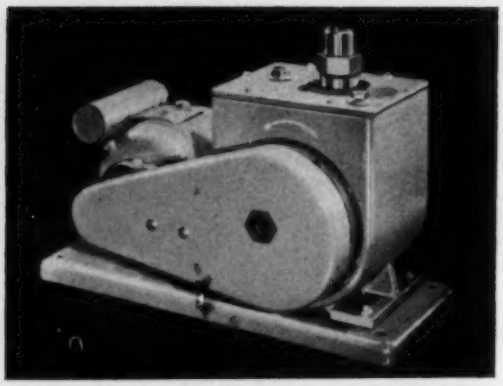

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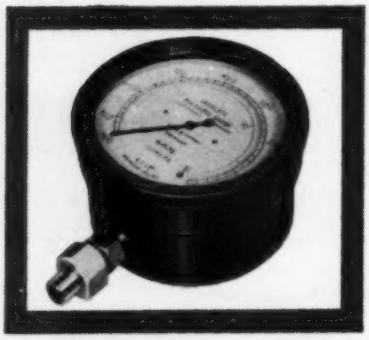

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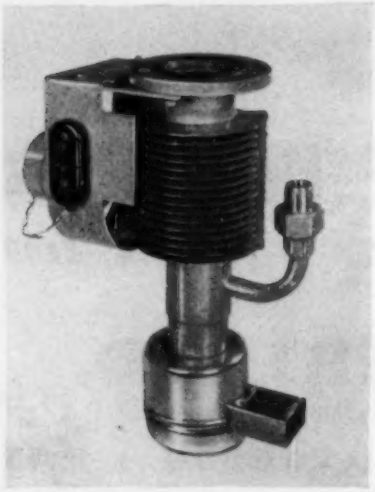

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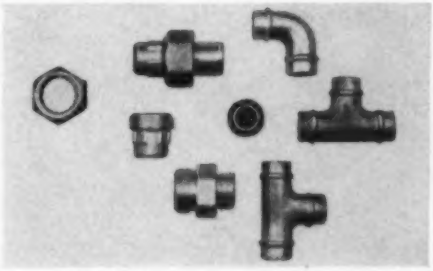

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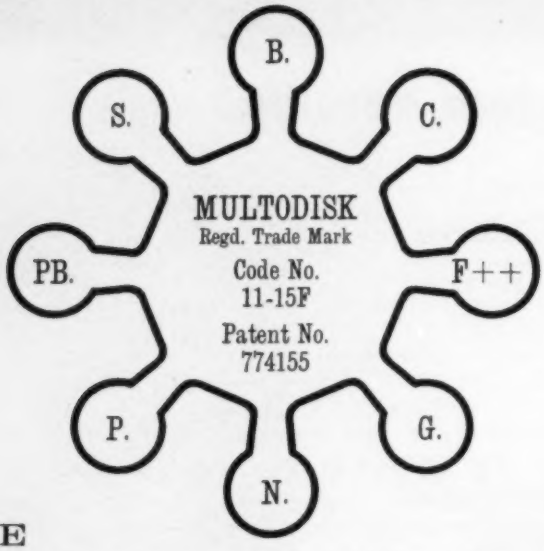

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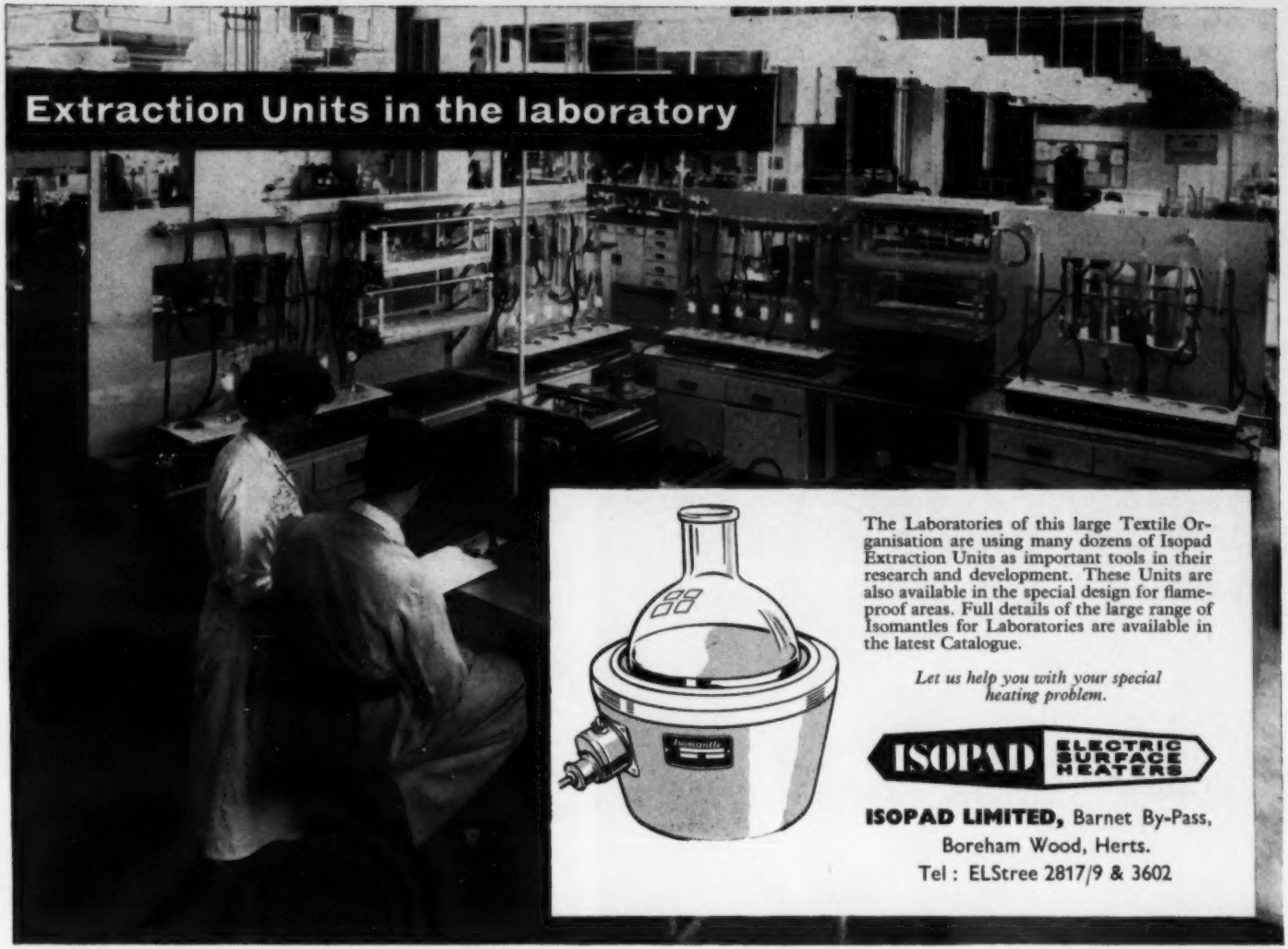

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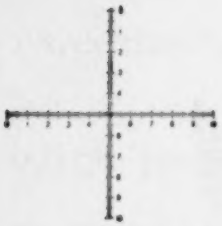
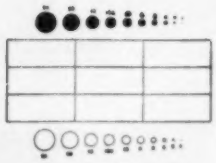
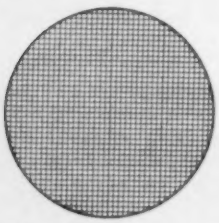
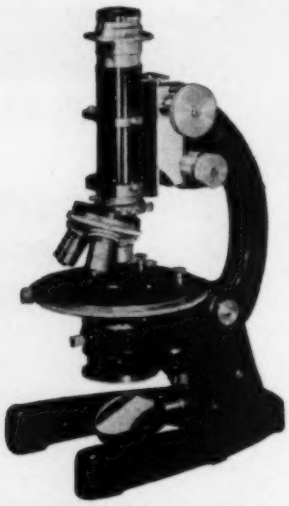
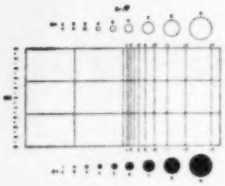
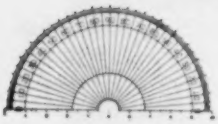
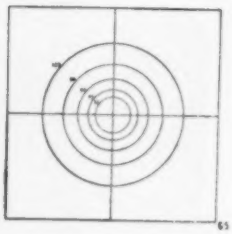

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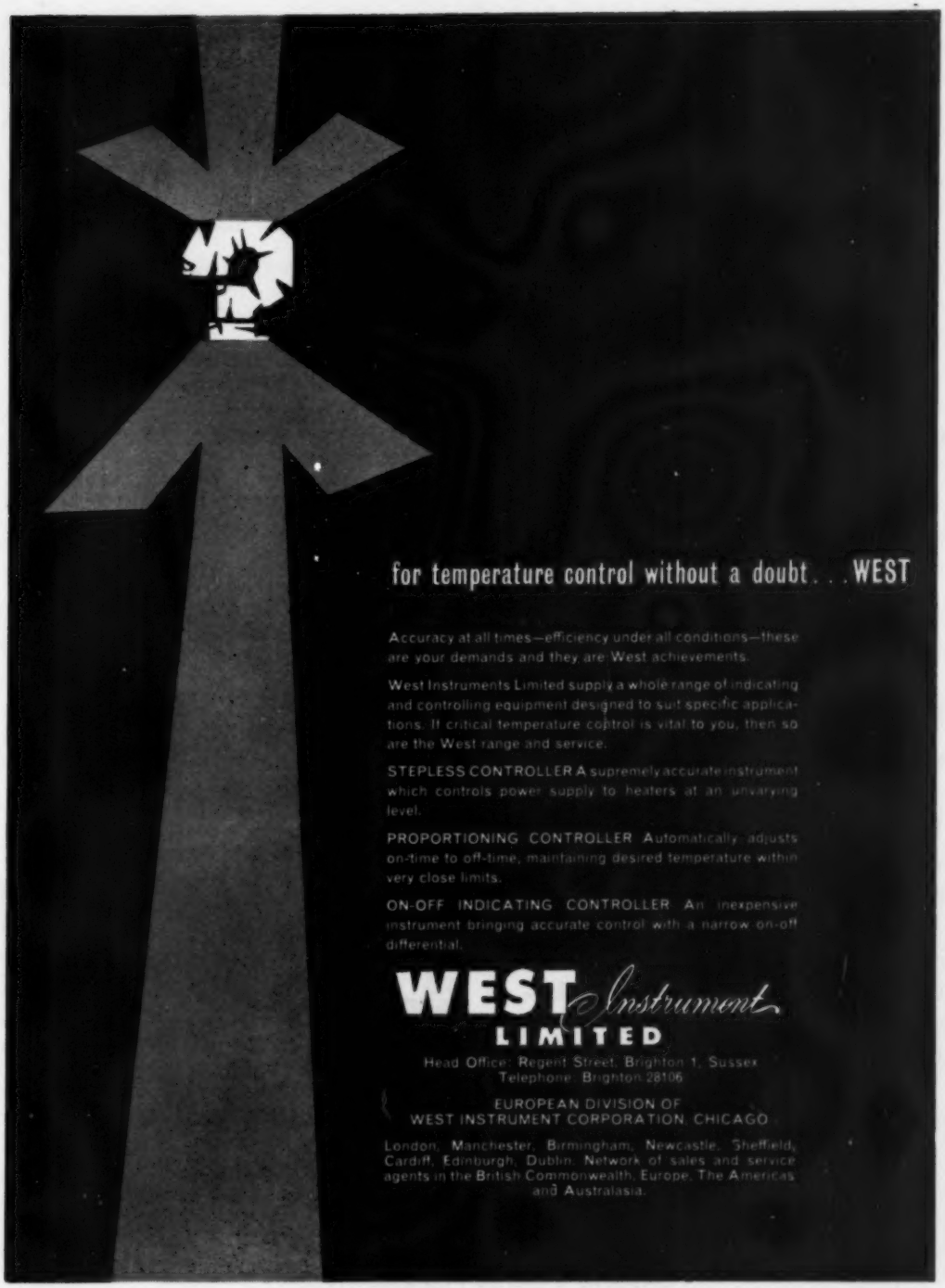
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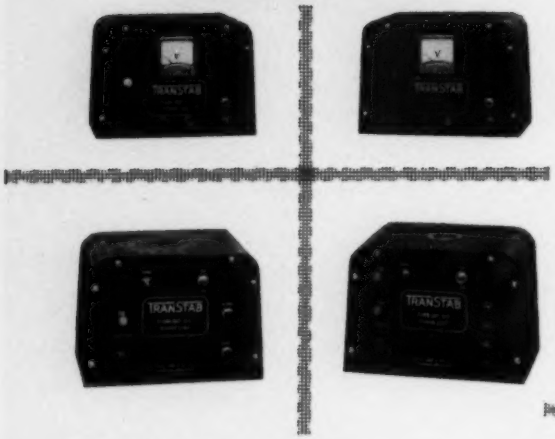

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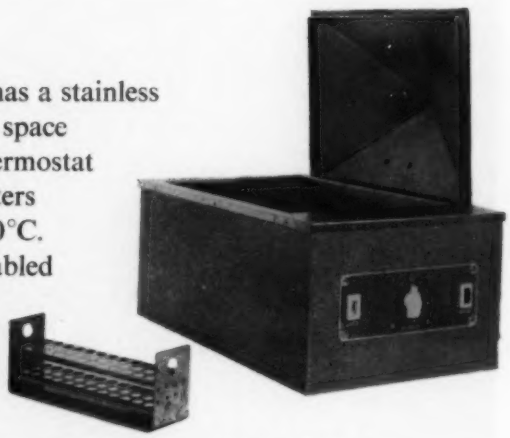

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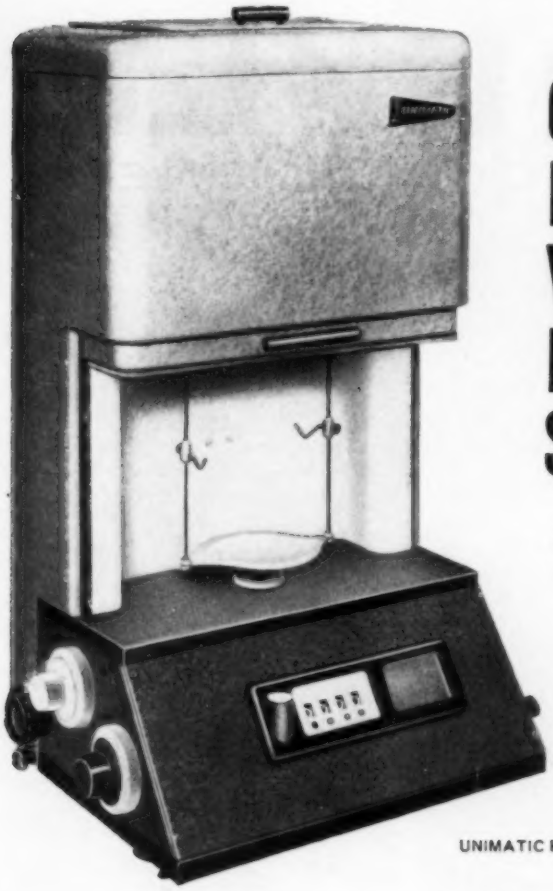

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EDITORIAL

Painless Extraction

SOME time ago we urged that the metric system and a decimal system for currency should be adopted in this country. Although reactionary elements have emphasized the cost of such a change, estimated at hundreds of millions sterling, there has recently been a marked revival of interest in the proposal. It is probably fair to say that today virtually all those who are familiar with both systems ultimately come to prefer the metric. The only advantage that can be claimed for the duodecimal part of our system is that 12 is divisible by 2, 3, 4 and 6, whereas 10 is divisible only by 2 and 5. However, a few school-boy problems involving complications in weights and measures will generally convert the most die-hard reactionary.

If it be conceded that a change should be made, the only question is then how best to make the change. Opponents have emphasized the chaos that would arise from starting the new system on a given date. We question whether it is necessary to bring about the change suddenly, and suggest that in many activities the change-over could be introduced over a period of years. The basis of our contention is as follows.

All persons have received the benefits of compulsory education and all, at any rate below the age of 65, are familiar with the general principles of the decimal system and have an elementary notion of metres, kilograms and litres. Many things are already discussed in terms of the metric system. The R.A.C. rating for motor car engines is now replaced by the size in litres, and all international sports and other activities such as the Olympic Games are organized on the basis of the metric system. Pharmacy now uses the metric system and medical workers are accustomed to it. British engineers are surprisingly adamant in their love for B.Th.U.'s and 'thous', but it is high time that all engineers and other technologists abandoned the ancient British systems and adopted the metric, for the same reason that we have abandoned the horse and cart and wooden ships.

We suggest that the British public could first be educated on the subject in the press, and on radio and television, and certain commercial transactions progressively put on a metric basis. Much confusion would arise if loose goods were suddenly sold on a kilogram basis, but there should be no trouble if packaged goods were altered in this way. The public would pay a slightly higher price for a quarter or half-kilogram than for a half or one pound, and no calculation would be necessary. Measurement of lengths of cloth and areas of materials and land should present no difficulty. New tape measures would not be a great expense. Once the public became accustomed to think in terms of kilograms and metres, an understanding of litres would not be difficult. Petrol and other loose liquids could easily be sold in litres, and scales for weighing solid goods could be fitted with new indicator strips.

Certain methods of selling would admittedly be difficult to adjust. Sales of liquids such as milk and beer, where the container defines the quantity sold, would clearly need special care and be somewhat costly, but overall the benefits of a universal metric and decimal system would easily justify all the trouble and expense. The importance of such a change in relation to the Common Market and export business, and even to world travel, needs no emphasis.

The decimalization of the coinage would obviously require a 'surgeon's knife' type of operation, but even here some preparatory work could be done. The half crown could be withdrawn with obvious benefits from this step alone. It has always been unnecessary. The ten shilling note could be given a specific name and the pound note gradually withdrawn. As it is, the fall in the value of money is making the five pound note of greater usefulness, and a note system based on £5 and its tenth part would be both logical and convenient. Here again withdrawal of the £1 note would eliminate the confusion that can arise through the similarity of the £1 and £5 notes. How Treasury officials, supposedly our most intelligent civil servants, can perpetrate such stupidities is a mystery that presumably will never be solved. Even a failed 11-plus child would not design two different currency notes to be so alike. The two notes should be markedly different in colour and design and reasonably different in size.

There are obviously many other ways in which the metric and decimal systems can be gradually introduced, and it should not be too difficult to get the whole population 'decimal minded'. In the past we have spent a lot of money and time on much less worth while things. As often happens, there is a general resistance to any new idea and later, after a 'softening-up' period, the new system is accepted quietly and without fuss.

Foreign Members of the Royal Society

At a recent meeting of the Royal Society the following were elected Foreign Members of the Society:

Holtedahl, Prof. Olaf.—Professor Emeritus of Geology in the University of Oslo and Member of the Norwegian Academy of Sciences, Oslo. Distinguished for his outstanding contributions to geology, particularly of Norway and the Arctic Regions.

Lefschetz, Prof. Solomon.—Henry B. Fine, Professor Emeritus of Mathematics in Princeton University, Princeton, N.J., U.S.A. Distinguished for his work in the fields of algebraic geometry and topology.

McCollum, Prof. Elmer Verner.—Professor Emeritus of Biochemistry in Johns Hopkins University, Baltimore, Md., U.S.A. Distinguished for his services to the science of nutrition.

Nesmeyanov, Academician Aleksandr Nikolaevich.—President of the Academy of Sciences of the U.S.S.R., Moscow. Distinguished for his contributions to organic chemistry, particularly on organo-metallic compounds.

ORIGINAL CONTRIBUTION

INTERFEROMETRY AS AN AID TO STUDYING COAL SECTIONS

by Professor S. Tolansky, D.Sc., F.R.S.

Royal Holloway College, University of London

It is shown how coal samples which have been polished by routine methods for microscopic examination can be studied by means of two-beam interferometry. Such an approach offers in a simple manner useful new information about the banded structure of coal. Notable differences appear between the interferograms of soft coal and anthracite.

SOME nine years ago (Tolansky, 1952) attention was drawn to the possibility of using interferometric methods to help in the study of polished coal sections. The proposal does not appear to have attracted much attention so that, with the intention of arousing new interest in this field, a brief report is now given of some new observations which indicate the type of information offered by such an approach. In illustration two-beam interferograms given by six different varieties of coal are shown here and very briefly discussed. The object is not to describe the specific characteristics of the particular coals, but to illustrate the usefulness of the technique in general.

The small coal blocks which were available, of size each about a cubic inch, had been prepared for standard normal microscope examination some years ago at one of the laboratories of the National Coal Board. A standardized polishing technique had been used, a technique worked out for friable coals. The blocks had first been ground on a metal lap using Carborundum F-powder and then rubbed on a glass plate with Carborundum No. 600 powder. Polishing was then continued on a machine with a velvet cushion charged with Microid 3/50 polishing powder and finally finished off by hand on chamois leather charged with polishing alumina, all of the processes being wet.

The six coal samples were:

A. Shire Oaks, Clowne, Bright.
B. Monk Bretton, Meltonfield, Bright.
C. Cannock Wood, Shallow, Bright.
D. Hought Main, Parkgate, Bright.
E. Hickleton, Barnsley, Banded.
F. Anthracite, Welsh.

The interferometric procedure adopted was of the simplest. A Vickers type inverted metallurgical microscope was used as it was then only necessary to prepare a single face of the specimen. Illumination was from a cooled mercury-vapour lamp, using a green filter. All the fringes shown were taken then with wavelength 5460 A. Excellent interferograms were obtained merely by placing the polished coal on a sheet of selected glass. As with all interferometry, care must be taken to illuminate at strictly normal incidence with parallel light, by having a small aperture at the focus of a good lens and arranging normal incidence to be checked by auto-collimation, which should be a standard procedure. All the interferograms shown here were taken with low power lenses and all are at linear magnification × 20.

Observations

Specimen A (*Fig.* 1).—This interferogram shows quite clearly that the surface has on it a number of bands, varying from say ½ to 3 mm. in width (taking account of the × 20 magnification in the print). The fringes show that the surface has some resemblance to the surface topography characteristic of say corrugated iron sheeting. However it is clear from the interferogram that the tops of the corrugations are relatively flat, smooth and uniform. They have also a reasonably good

Fig. 1.

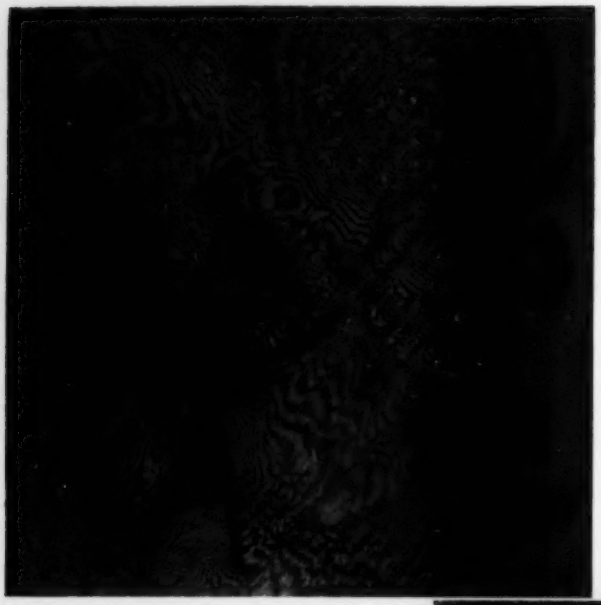

Fig. 2 (*left*).

Fig. 3 (*below*).

specular reflectivity. The troughs between the crests are some 2½ microns in depth, are fairly narrow and have steeply falling sides. Pieces are missing in various regions and it is notable that these holes, of depth perhaps 8 microns or so, have the shapes of elongated strips lying in a direction more or less perpendicular to the direction of the large scale corrugations.

In several regions distinctive height discontinuities can be identified, rather resembling the familiar discontinuous steps shown by those crystals which cleave regularly.

Specimen B (*Figs.* 2 *and* 3).—This sample also reveals a banded structure but here it is clearly seen that the long main corrugations are crossed at about right angles by a well marked secondary waviness which is on a much smaller scale. These two illustrations are from different regions but show close similarities.

The sample in Fig. 3 shows several features of interest. Isolated by cracks, the central (near-square) region exhibits fringes which indicate that this crack-bounded section is smooth, slightly cylindrical, yet also corrugated on rather a broad scale, such that the whole piece essentially encloses a single corrugation. Yet noticeable here, as in Fig. 2, are the small scale secondary corrugations crossing at right angles to the main feature. These secondary features are some half a millimetre wide and usually only about quarter of a micron in depth. It will be noted that outside of the central block the surface tilts away rapidly, yet still maintains the double-banded character.

Specimen C (*Fig.* 4).—In this sample we have a surface which hardly shows any fringes at all. The inference is that only over small fractions of the surface area (that where fringes appear) is there any approach to true specular reflectivity. For it is a matter of experience that a matt surface does *not* show interference fringes. Fringes only appear where there is

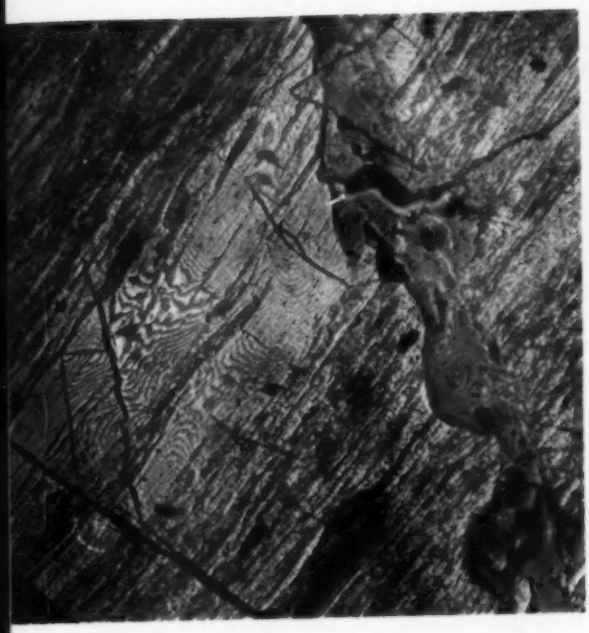

Fig. 4.

Fig. 5.

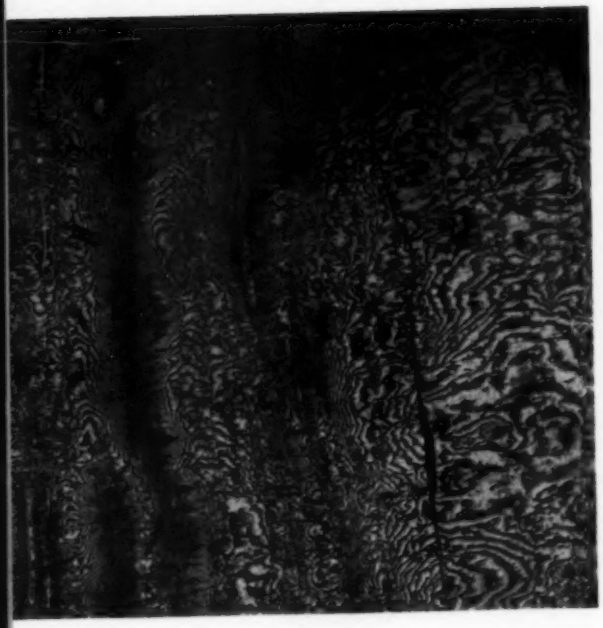

Fig. 6.

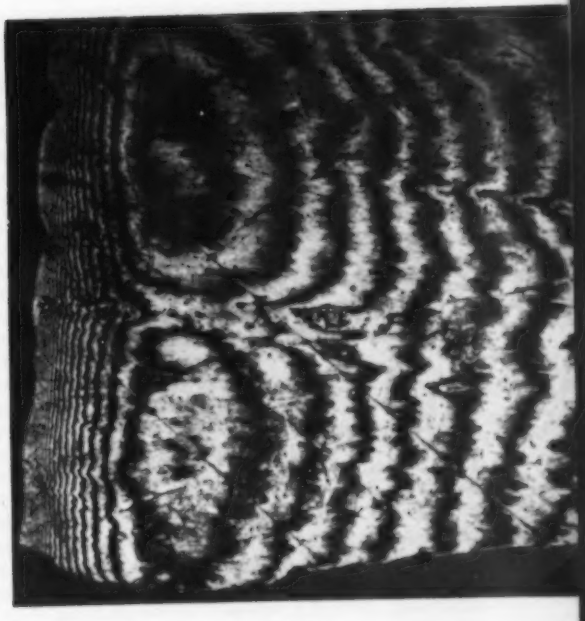

Fig. 7.

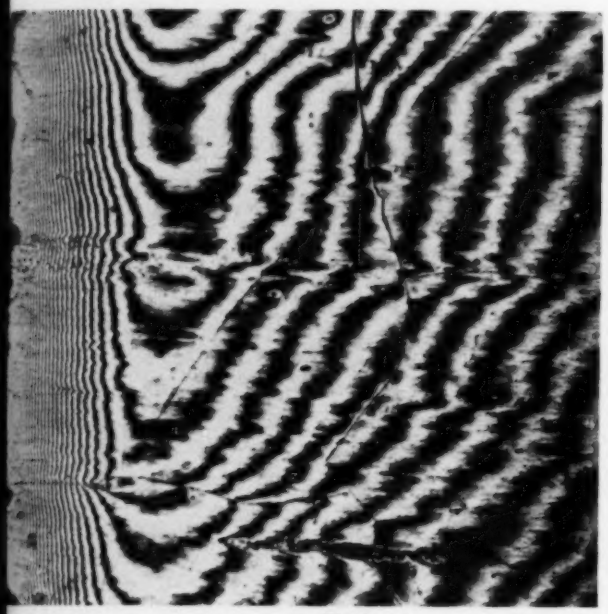

Fig. 8.

specular reflectivity, because the scatter from matt surfaces destroys the necessary phase relation condition needed for interference.

Thus the very poor character of the fringe pattern here offers positive information that the specimen is not accepting a specular polish. This in itself is useful information.

Even so, in the few regions where fringes are discernible, albeit of poor visibility, topographic material of interest can be extracted. There is for instance a rectangular 'cleaved' section between roughly rectilinear crack-boundaries and within this small region the fringe pattern shows (*a*) that reflectivity in this block is specular, (*b*) there exists a secondary discontinuous cleavage within this small block, as witnessed by an abrupt change in fringe orientation near one corner. Thus even the very absence of a fringe pattern gives useful information.

Specimen D (*Fig.* 5).—This sample reveals a vivid interference pattern which at first sight resembles that in Fig. 1 yet a closer examination reveals several differences. In Fig. 1 there are banded regions which are essentially corrugations with the character of broad, flattened, ridges, flanked by narrow steep-sided valleys. Here on the contrary we have banded regions which are nearly at the same level. As it is easy, by several independent methods, to determine which is up and which down, it can be shown that the narrow band regions are in fact standing *up*, slightly proud. Thus we have here regions of markedly different specular reflectivity, with the non-specular bands being slightly elevated.

The conclusions are obvious. In Fig. 1 the narrow bands are probably softer regions than the surround and have been preferentially abraded away during the polishing process, leaving deep valleys. In Fig. 5 on the other hand the narrow bands are slightly harder regions than the main surround and polishing has both left the region standing proud and also failed to produce a specular finish.

Specimen E (*Fig.* 6).—Described as a 'banded' coal, this specimen has a very rough surface structure compared with the previous sample. Yet even here two sets of roughly perpendicular corrugated patterns are apparent.

Specimen F (*Figs.* 7 *and* 8).—The interferograms of Figs. 7 and 8 were given by two different pieces of polished Welsh anthracite. It is quite evident that the surface character on both is totally different from that of the soft coals. Indeed the finish and polish taken are such that the surface structure is not very different from that of crudely polished glass. Thus the excellence of the fringe contrast indicates that the surface reflectivity closely approximates to that of glass, for of course maximum visibility occurs when the two surfaces involved in interference have identical reflecting coefficients. There is no evidence at all of the existence of any major banding effect although secondary bands of quite minor amplitude are clearly discernible. The surface finish is exceptionally good, local polish mark wriggles and defects being little more than one-twentieth part of a micron. Whereas all the soft coals show local deep holes in which a good depth of material is absent, this is not so on the anthracite surface which is as compact as that of a glass or a typical metal.

While it will be agreed that there is reasonable similarity between the interferograms of the soft coals, so different are the two anthracite surface patterns that it is quite impossible ever to mistake one type for the other.

Conclusion

The purpose of this paper is to show that by very simple means coal specimens prepared for microscopic examination can readily be studied with two-beam interferometry and that this offers much additional information with very little effort. It will clearly be worth while examining prepared surfaces both parallel and perpendicular to the level of layering. Anthracite can cleave with a clean and shiny enough finish to permit of study of the cleavage regions directly without any polishing and by this means fracture behaviour can be studied.

In both Figs. 7 and 8 the crowding in of fringes near the specimen edge is merely evidence that during polishing preparation the edge has rounded off, a fairly normal effect. Notable in Fig. 8 are the occasional sharp discontinuities bounded by crack lines.

REFERENCE

Tolansky, S. (1952). Nature, **169**, 660.

ARTICLES

THERMOGRAVIMETRIC ANALYSIS

by G. M. Lukaszewski, Ph.D., and J. P. Redfern, Ph.D., A.R.I.C.

Battersea College of Technology

PART I—INTRODUCTION

The purpose of this series of articles is to present thermal analysis, in particular thermogravimetric analysis, as a technique which can be used to advantage in various fields of chemistry either alone or in conjunction with other methods.

Historical Introduction

Gravimetric analysis is one of the oldest operations in analytical chemistry, being involved in practically all quantitative operations. Whilst the results obtained may be used for purely analytical purposes, it is possible to extend them so that they may provide other information. Normally the operation concerned with the determination of mass is carried out at room temperature even if the substance under consideration has previously been heated. Sometimes information is required on the phase changes involved when certain materials are heated in air. It is then the practice to express the results as 'heating' or 'pyrolysis' curves showing the weight loss (or gain) of the material at various temperatures. If the material is studied by any discontinuous method (i.e. by heating to a known temperature, cooling and weighing, with subsequent repetition of the cycle for a higher temperature), it is most tedious to perform and suffers from a number of disadvantages:

(i) The possible reversibility of the process, due to the uptake of atmospheric moisture on cooling.

(ii) The likelihood that any reaction, once initiated at a particular temperature, would not cease immediately on cooling the sample, so that the weight recorded would not be a true measure of the weight at the temperature for which data was required.

(iii) The detail of such curves would depend upon the range of temperature over which the material was heated, and upon the number of samples examined (or the number of times the cycle was repeated). In order to gain maximum information the number of samples examined should be very large and, ideally, approach infinity.

Attempts have been made to simplify these methods for determining the pyrolysis curves of various compounds. Thus methods which involve continuous heating of the material coupled with a means of simultaneous measurement of mass and temperature have been developed by a number of workers. Such combinations which comprise a furnace used in conjunction with a balance (generally termed a thermobalance) introduce certain practical difficulties. These problems and the ways in which they can be overcome are outlined later.

Full reviews of the development of thermogravimetry and of the thermobalance have been given by Vigneron (1949) and by Duval (1953). The term thermobalance appears to have been introduced by Honda in 1915. The work of Guichard and his school from 1925 onwards and the introduction of automatic recording instruments by Chevenard and his co-workers in 1944 opened up the field of thermogravimetric analysis. Duval and his co-workers used a modification of the Chevenard balance for the study of some 1,200 inorganic gravimetric precipitates. Various Japanese workers used a modification of the Honda thermobalance in work involving controlled atmospheres (*see* e.g. Noshida, 1927).

It is possible to obtain valuable semi-quantitative results from simple apparatus; thus in 1951 Burriel-Marti and Goyanes recommended the use of a 'rapid' apparatus which comprised an ordinary, suitably modified, semi-micro balance in conjunction with a furnace. This suffered from the disadvantages of subjecting the knife-edges and planes of the balance to heavy wear due to continuous contact. Wilson (1959) has described a simple torsion balance with an ordinary furnace which has proved useful in the teaching of the principles of thermogravimetry.

Various commercial instruments are available which are both elaborate and expensive but yield accurate results. Automatic weight loading and the simultaneous recording of changes of both temperature and weight are often used in commercially available thermobalances. Provision is sometimes made for the interruption of the pre-set programme of heating. Thus, where it is to be expected that the weight of the sample will remain constant for a wide temperature range, it is possible to save time by increasing the rate of heating for a period, and to return to the original rate when a change in mass is expected. Such provisions greatly extend the scope of the instrument.

Requirements for a Thermobalance

In order that the maximum benefit may be derived from investigations in this field the instrument used must possess certain features. It is not the purpose of this article to discuss the relative merits of individual thermobalances but to suggest a series of criteria which

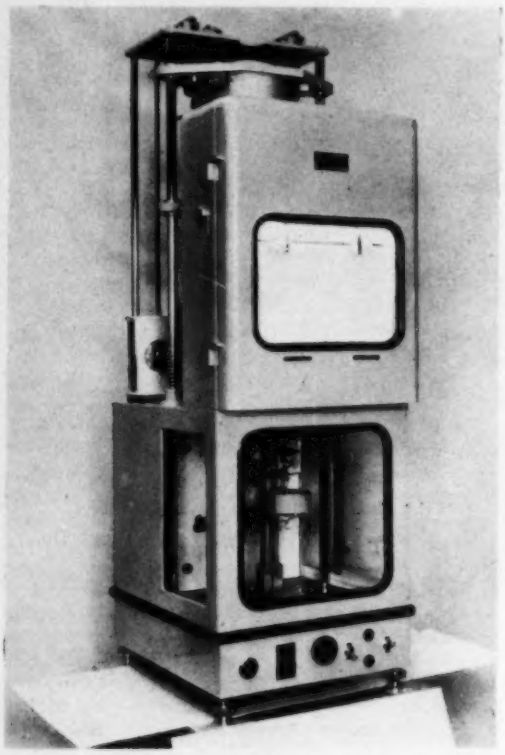

Plate I. By courtesy of Stanton Instruments Ltd.

can be applied in considering any single instrument.

Some factors which have to be considered are:

(i) That the thermobalance should be capable of registering the weight-loss (or gain) of the material studied as a function of both time and temperature.

(ii) That the thermobalance furnace should have a wide range of operation, e.g. from room temperature up to 1,500°C.

(iii) That the weight loss and temperature should be recorded with accuracy, usually better than 0·01 per cent in the former case and within $\pm$ 1° in the latter case.

(iv) That physical effects due to the normal functioning of the apparatus do not upset the accuracy of the balance, e.g. the radiation and convection currents, and the magnetic effects due to the winding of the furnace should be negligible. Also that the latter do not interact with any conducting or magnetic materials that may be studied.

(v) That the position of the crucible within the furnace of the thermobalance is always the same, so that the temperature recorded corresponds to the temperature of the material.

(vi) That the furnace may be equipped to allow for the heating of materials in various atmospheres.

(vii) That the instrument is as versatile as possible providing for variation in the rate of heating together with automatic control of the programme.

(viii) That the balance is adequately protected (*a*) from the furnace, and (*b*) so that the wear of the knife edges and other moving parts is reduced to a minimum and accuracy of weighing is assured.

(ix) That the thermobalance can be periodically checked to ensure accuracy of operation.

(x) That the chart used to record weight loss and temperature rise can be run at various speeds and that there is provision for accurate recording of a suitable time interval.

Not every instrument can possess all these features. Plate 1 shows one of the commercially available thermobalances which incorporates many of these features and, in addition, is available in several modifications.

Principles of Thermogravimetry

With a thermobalance incorporating the features discussed above, the thermal decomposition of materials is found to depend primarily on the rate of heating. It is important to note that certain physical factors can affect the temperature of decomposition quite markedly:

(i) The amount of the sample being used.
(ii) The particle size of the material.
(iii) The packing of the material.
(iv) The size and form of the crucible used to contain the sample.

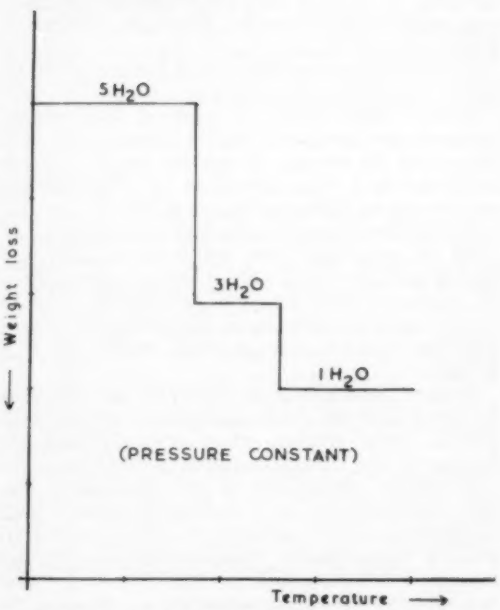

Fig. 1. Ideal pyrolysis curve dehydration of $CuSO_4$ $5H_2O$.

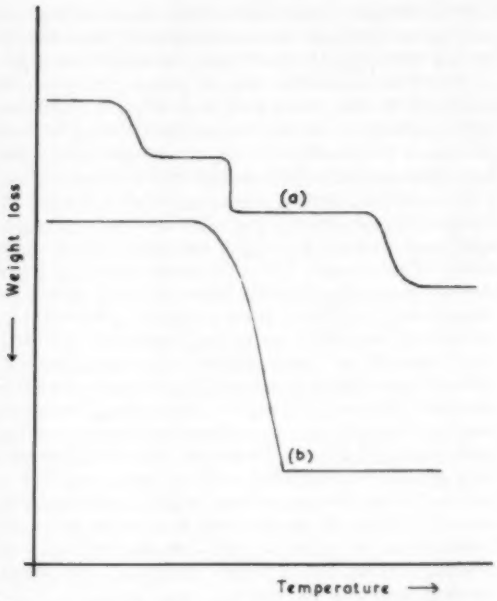

Fig. 2. The normal pyrolysis curves. Thermogravimetric curves obtained in practice for (*a*) calcium oxalate dehydrate, (*b*) ammonium sulphate.

(v) The actual atmosphere surrounding the sample —including the influence of convection currents.

These factors are very important especially if the investigation is concerned with kinetic measurements or the study of reactions in the solid state. In a series of investigations it is advisable to keep constant as many of the factors as possible and to retain a record of the conditions used, as these may be of considerable value in the interpretation of results.

Pyrolysis curves of a substance depend on:
(*a*) Nature of the material.
(*b*) Rate of heating.
(*c*) The speed at which decomposition is recorded.

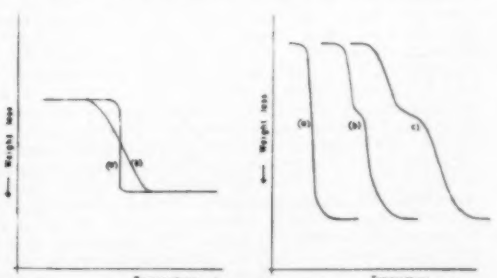

Fig. 3 (*left*). The effect of heating rate: (*a*) rapid, (*b*) slow. Fig. 4 (*right*). The formation of intermediates: (*a*) fast heating rate, (*b*) slow heating rate, (*c*) slow heating rate and recording rate.

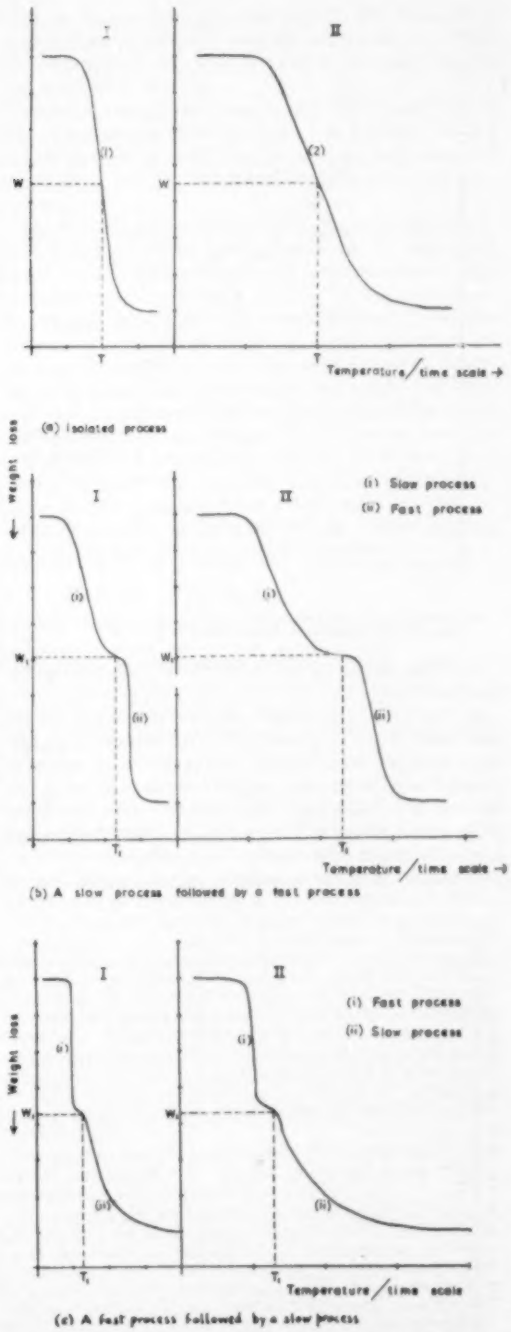

Fig. 5. The influence of chart speed upon the shape of the thermogravimetric curve. Curve I, slow chart speed. Curve II, fast chart speed.

that the final stages of decomposition are not too slow. which is independent of *t*. (*see* Fig. 6). The limitations

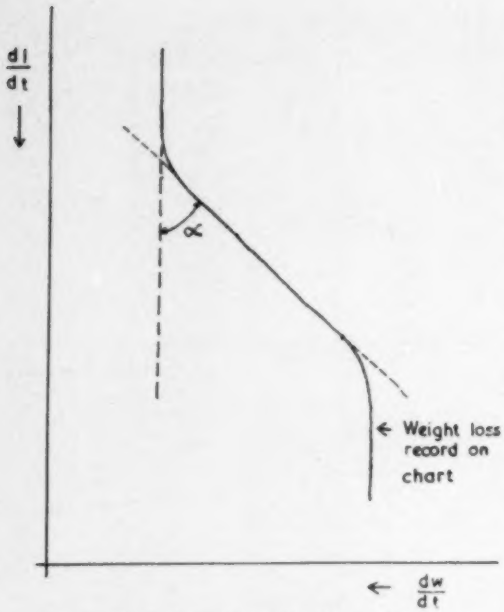

Fig. 6. The resolution factor ideally $\alpha = 45°$.

(*a*) is the subject of the investigation and will not be discussed here.

(*b*) *The rate of heating*.—In general, except in the ideal case (Fig. 1), pyrolysis curves seldom undergo sharp changes of direction. The more usual curve is rounded and possesses a sigmoid appearance (Fig. 2). The rate of heating may often markedly alter the shape of the curve obtained. Thus with a material that undergoes a fast irreversible reaction the heating rate will have little effect upon the recorded pyrolysis curve. For a slow irreversible process the extent of decomposition at a given temperature depends upon the time of heating. The pyrolysis curve may show different types of behaviour when the rate of heating is rapid as compared to that when it is slow (Fig. 3); with the former inflections of the curve corresponding to real changes in the composition may readily be missed. The final assessment of a curve should therefore be based on a slow rate of heating when appreciable changes in composition are occurring and a faster rate when no significant changes in weight are taking place; (this implies that to gain full information on a material several runs, using different rates of heating, should be carried out). It has proved possible sometimes to isolate and to confirm by analysis and other methods the formation of intermediate compounds initially indicated by a slight inflection of the pyrolysis curve at a particular temperature (Fig. 4). It must be remembered that the temperature is constantly changing, whilst under static conditions of study the material is brought to a specified temperature and so maintained for a period of time. Attention should be paid to the recorded rate of change of temperature at a time when an inflection in the pyrolysis curve is observed, because this may be caused by a sudden variation in the rate of heating, and hence be false.

The provision for interrupting the programme of a uniform temperature rise and continuing the heating at a steady fixed temperature is a useful asset, especially where slow processes are involved. This technique, termed quasi-static, offers a superior route to the resolution of thermal decomposition curves of high complexity. The quasi-static method furnishes pyrolysis curves which are, in general, steeper than their 'dynamic' counterparts. For decomposition of pure materials the shape of the curve is often not important, the extent of the loss being all that is required. The recorded loss will not differ appreciably from the true value, provided

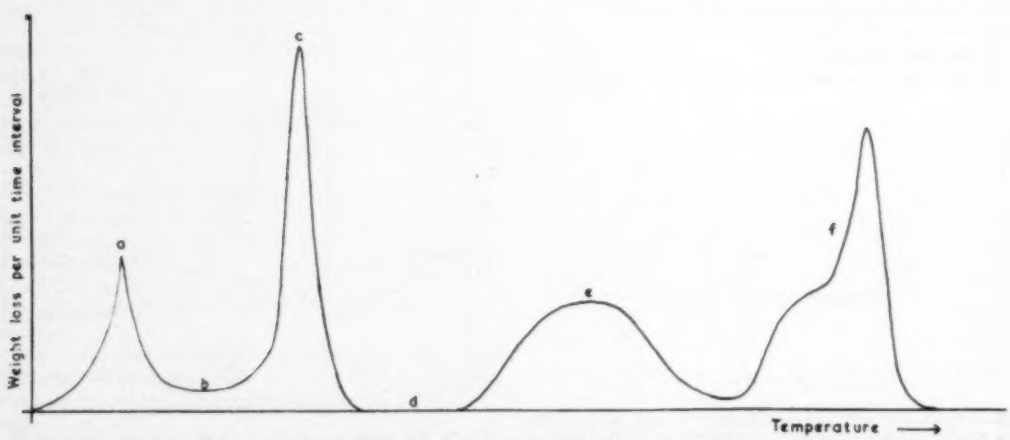

Fig. 7. D.T.G. curve extracted from normal thermogramme. (*a*) and (*c*) well-defined stages with fast change and loss, (*b*) inflexion, (*d*) plateau, (*e*) slow stage, (*f*) two stage loss.

that the final stages of decomposition are not too slow. In some cases it is difficult to ascertain when the reaction is complete because loss occurs progressively with increasing temperature at rates which are persistently very slow, (i.e. loss is asymptotic with time or temperature). This difficulty can sometimes be avoided by altering the programme.

(*c*) *Recording or chart speed.*—Recording speed affects the resolution of successive steps in a thermal decomposition. In the recording of either fast or slow processes the recording speed of the instrument can have a profound effect upon the shape of the curve obtained. Fig. 5a shows the flattening produced in the curve for a slow process by increasing the chart speed. In Fig. 5b a slow process (i) is followed by a faster process (ii) recorded with a fast chart speed (Curve 2). Curve 1 represents the same sequence recorded with a slow chart speed in which it may be seen that the curve now fails to resolve clearly the two steps of the decomposition. Fig. 5c depicts a fast process (i) followed by a slow process (ii). Curve 2 represents the results recorded with a fast chart speed whilst Curve 1 represents the same sequence recorded with a slow chart speed. Again, the effect of a fast chart speed is to improve the resolution. It is useful to define a factor R, the resolution factor, as follows: For a recording chart speed of 1 cm./minute and a weight loss at time t represented on the chart by dw cm./minute. The shape of the slope at time t depends on both chart speed and the weight scale g. per cm. Thus $R = \text{Tan } \alpha = \frac{dw}{dl}$ which is independent of t. (*see* Fig. 6). The limitations on R are the chart speed and the weight scale, a value of α around 45° or $dw/dl = 1$ being desirable for the mid-point of a reaction.

It should be said that an excessive chart speed would tend to smear out differing rates of weight-loss. In fact a chart speed of some 6-12 inches/hour for a temperature rise of from 1-6° per minute is adequate for most purposes.

The form of pyrolysis curves are thus very dependent on both the rate of heating and on the recording technique. It is advisable to carry out a number of runs in which these factors are altered so that maximum information is obtained. In presenting results all the relevant data should be recorded. Results for thermogravimetric studies may be expressed in several ways, e.g. weight-loss with temperature, or weight-loss with time. It is sometimes useful to express the results in the form of a plot of the rate of weight-change per unit time against the temperature (Fig. 7). Such plots may readily be extracted from the standard thermogravimetric record providing it has a time base.

The next article in the series will be concerned with the applications thermogravimetric analysis.

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Meldola Medal Award, 1960

The Meldola Medal for 1960 has been awarded to John Newton Bradley, for his work in the field of physical chemistry, with special reference to the kinetics of reactions involving free radicals and reactions in shock waves studied by mass spectrometry.

J. N. Bradley was educated at Humbersone Foundation School, Cleethorpes, and at Birmingham University where he was awarded First Class Honours in the B.Sc. Chemistry degree and was winner of the Frankland Prize in 1952. From 1952 to 1955 he carried out research under the supervision of Sir Harry Melville and Prof. J. C. Robb on the reactions of simple alkyl radicals in the gas phase. During this period he was successively Priestley Scholar (1952-1954) and University Research Scholar (1954-1955). He received the Ph.D. degree in 1955 and entered the Royal Air Force in the General Duties (Pilot) Branch with the rank of Pilot Officer. He completed advanced flying training in 1957, receiving the Flying Trophy and Ground School Trophy for his course. During the remainder of his commitment, he served with No. 99 squadron, R.A.F. Lyneham, with the rank of Flying Officer. In August 1957 he was awarded a Commonwealth Fund Fellowship, tenable at Harvard University, and worked there with Prof. G. B. Kistiakowsky until June 1959. At this time he was appointed Lecturer in Inorganic and Physical Chemistry in the University of Liverpool.

Dr. Bradley has studied the reactions of simple alkyl radicals by the molybdenum oxide diffusion technique and by mass spectrometry. In addition to establishing rate constants for various reactions, he demonstrated the dependence of the relative rates on the presence of 'hot' (energy-rich) radicals.

At Harvard University he became interested in reactions in shock waves and, with Prof. Kistiakowsky, he developed a time-of-flight mass spectrometer which would analyse the gas behind the reflected shock wave while reaction was proceeding. He studied the kinetics of nitrous oxide decomposition and was able to observe the build-up of oxygen atoms prior to the establishment of a steady state.

This was followed by a study of the pyrolysis and oxidation of acetylene. Polymeric species were detected in both cases, although different in nature and in mode of formation. Several of the primary processes occurring were resolved by this work.

Dr. Bradley has also investigated the thermal decomposition of nitroparaffins in the gas phase and some of the reactions of methylene in the liquid phase.

Current research interests include the emission from shock-heated gases, the mechanism of thermal ionization in shock waves by mass-spectrometry, the combination of flash photolysis and shock tube techniques, the latter being used for ultra-rapid flow generation, and the development of a modified 'chemical' shock tube with improved time resolution, subsequent analysis being based on vapour phase chromatography. Both theoretical and experimental work is continuing on the reactions of free radicals at normal temperatures.

VARIATIONS AND ERRORS IN EXPERIMENTAL INVESTIGATIONS

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PART IV—LIMITATIONS OF CHEMICAL TOOLS AND TECHNIQUES

A GIVEN chemical problem may be investigated by means of different tools and techniques. Such physico-chemical tools are concerned with definite fields. Theoretically they are limited by certain considerations; practically they are controlled by original design and by experimental limitation. Each of the tools used has its advantages as well as strict limitations. The limitations on each tool impose in turn a limitation on the interpretation of the results, and it is desirable to examine critically the individual limitations of each tool and associated methods in order to assess the suitability of a particular technique for a given investigation. The number of physico-chemical tools available is now considerable, e.g. electrometric measurements (such as e.m.f., polarography, conductivity and pH determinations) optical measurements involving absorption spectra, birefringence, light scattering and refractive index determination; paper chromatography, low and high voltage paper electrophoresis and zone electrophoresis; vapour phase chromatography and automatic methods including electronic recording.

The limitations of a technique are determined by the inherent limitations of the approach, equipment used, and by the experimental conditions themselves. They vary from one technique or tool to another. It is possible to point out only a few of the variations and errors encounterable when a given tool is used. Many of those encountered can be conveniently classified under the following headings:

1. Limitations due to incorrect interpretation of the capacity of the tool. (Sometimes these are due not to the individual chemical tool or technique used, but rather to the difficulty of ensuring standard 'experimental conditions' such as standardized reactant material required for the measurement of the particular property).
2. The extension of the use of the tool beyond its original concept or design.
3. 'Experimental error.' This limits the degree of accuracy.
4. Time variation. The standardization of calibration of a given instrument can vary over a given time interval. The apparatus then requires re-setting, thus limiting the number of measurements that may be carried out over a given time. This limits the use of the instrument in so far as rates of reaction are concerned.

A special problem arises when a given system which performs a definite function is made to operate under a different set of conditions than for which it has been planned. Such a change represents a source of error which may be ascribed to the limitations of a new tool or technique being used. The source of error may be illustrated in the case of paper chromatography and paper electrophoresis. A certain buffer solution may be used for controlling the pH. However, if used as a buffer in paper chromatography and paper electrophoresis its pH is bound to alter. This is due to the components of the buffer possessing unequal mobilities. The pH of a buffer composed of a weak acid and its salt is determined according to the Henderson-Hasselbalch equation, viz.:

$$pH = pK + \log \frac{[salt]}{[acid]}$$

The buffer is made up of a definite proportion of the salt (anion) and the free acid. The velocity of the anion over the paper, following its absorption and desorption in paper chromatography, is bound to differ from that of the free acid, thus resulting in increasingly different ratios of salt/acid and therefore in different pH values. If the pH dependence of the R_F value is small the effect may be missed. However, in many cases such dependence is quite pronounced. In paper electrophoresis we have the possibility of a similar phenomenon. The anion is bound to move far more rapidly under the influence of the electrical field than the free acid. Further the effect will become more pronounced as the distance from the origin increases. Consequently considerable differences may be expected in the pH values along the paper. The same principle may be applied to zone electrophoresis. The effect depends obviously on the magnitude of the potential gradient encountered. (The above effects are considered. along with experimental evidence, elsewhere (Lewin, 1961)).

It is not possible to consider in detail all or even one of these techniques in a short paper. Here, it is proposed to consider very briefly the outstanding limitations which may be encountered in the uses of some of these tools.

(a) *Glass electrode pH determinations*—The accuracy of this tool is limited by the valve potentiometer (or other instrument) used, the type of glass electrode, and by the significance of the electromotive force measured, i.e. in the interpretation of the values so far as conversion of e.m.f. to pH values is involved, which involves some thermodynamic uncertainty. Commercial valve and vibrating condenser potentiometers are now available which are capable of measuring accurately to 0·1 millivolts or to *ca.* ±0·001 pH units. However, the best commercially available glass electrodes give repro-

ducible results only to within ±0·002 pH units in well-buffered solutions under standardized conditions. The significance of the experimental values depends in turn on the theoretical accuracy of standardizations with buffers such as borate, phthalate and phosphate, the individual pH values of which are, however, established with certainty only to the second decimal (National Bureau of Standards, 1950). The uncertainty is caused partly by the difficulty of formulations of the individual activity coefficient of the hydrogen ions in its relation to the geometric mean one which involves the co-ion present (Lewin, 1960) and partly because of the uncertainty involved in assessing accurately the values of liquid-junction potentials involved. The limitations become more pronounced in very acid or very alkaline solutions which involve significant corrections even when electrodes more 'docile' than the sodium glass electrodes are used.

The above considerations are valid at any single temperature used. Further, fundamental limitations are involved when an investigation involves several temperatures, because the problem of the relationship of pH values at one temperature to those at other temperatures is involved. It should be remembered that the basis of the pH scale is that the e.m.f. value of the hydrogen electrode is zero *at all temperatures*. When only one temperature is employed the *comparison* of the various pH values at the same temperature is unaffected. However, the uncertainty as to the exact relation between the pH scales at two different temperatures is bound to involve an element of uncertainty as to the exact value of temperature effect on properties which depend on the pH value.

A further limitation arises when small particles and biological cells are involved. It has been deduced by Hartley and Roe (1940) that the pH value at the surface of a suspended particle is not the same as that of the bulk of the solution. These authors have formulated the relation as

$$(pH)_{surface} = (pH)_{bulk} + A\bar{v}$$

where A is a constant the value of which is 0·217 at 25°C. for micro-organisms and particles of bacterial dimensions, and $\bar{v}$ is the particular electrophoretic mobility. The correctness of this relation has been demonstrated experimentally, and the difference between the two pH values has been assessed to be roughly 0·4 pH units. The electrophoretic mobility is affected significantly by ionic strength and other factors and the error involved may well influence the significance of the experimental pH values which are carried out on the bulk of the solution.

The degree of accuracy required is often the factor limiting the use of a particular tool. This is conveniently illustrated in glass electrode pH determinations.

Several commercial pH meters have scales which read ±0·01 or ±0·02 pH units. Such limitations are sometimes considered reasonable in determination of pK values, particularly if the results are accurately reproducible. There are however cases where this degree of accuracy is insufficient. It is not possible to lay down a fast rule, but generally speaking comparisons between different systems which involve pH or pK differences of the order of 0·05 pH units require apparatus capable of reading accurately to values better than 0·01 pH. This is so because a variation of ±0·01 is essentially a variation of 0·02 pH units which in relation to a 0·05 difference becomes quite significant. This applies particularly in biological work where 'biological variations' may cause further experimental errors which could upset the validity of the conclusions based on small differences. Differences of the order of 0·04 pH units are known to be significant in biological work and there it is essential to have instruments capable of a degree of accuracy better than 0·01 pH units. For example, Weir (1955) has recorded that in the case of mice, males belonging to a line having an average blood pH value of 7·42 increased the female/male sex ratio in the offspring from 50:50 to 60:40, while the other parent male line having an average blood pH of 7·46 decreased the sex ratio to *ca.* 40:60. The blood pH value of the mater appeared to be without effect. It is obvious that the use of a pH meter correct to 0·02 pH units would have cast doubts on significance of the results.

pH values are generally used for the determination of pK values of acid and base groups. These measurements are usually constant over a reasonable length of time. Thus in the titration of acids and bases having single acid or single base groups, such as acetic acid or ammonia, or more complex ones involving both acid and base groups, such as adenosine or lysine, addition of a given quantity of titrant results in a definite pH value which is retained over at least several hours. The experimental variation there is usually within ± 0·01 pH units. Sometimes, however, pH changes take place quickly because of decomposition or other changes, e.g. isomerization. These changes are sometimes so rapid that continuous measurements are desirable. It is in this particular field that automatic recording is most important, because the ordinary glass electrode pH meter cannot be used to record the readings sufficiently rapidly. It should, however, be remembered that the use of automatic pH recording suffers from specific limitations. First, the glass electrode cannot be re-standardized without interruption of the recording. Second, slow attainment of equilibrium results in slow attainment of associated pH value; thus the use of a recorder for following continuous acid-base titrations does not allow checking of the steadiness of pH values on addition of definite quantities of titrant. The same point applies, within the time interval between individual addition to the titrant, to manual pH meter measurements. These points are of fundamental importance. This has been illustrated in the amino acid-glucose interaction (Lewin, 1956, 1957; Lewin and Kosinski 1958; Lewin and McCall, 1957) where a series of steady pH states have been found subsequent to the first steady pH state of 'equilibrium'. Third, the

probability of an instrumental error is increased by the use of recording instruments, and rechecks and re-calibrations are necessary to ensure the correctness of he obtained results.

(*b*) *Paper chromatography*.—Paper chromatography has proved to be an elegant analytical tool capable of a high degree of accuracy provided the conditions are *strictly standardized*. Nevertheless effective limitations are encountered time and again in both theory and practice.

On the theoretical side it must be emphasized that paper chromatography is conveniently applicable to chemically *static* systems, i.e. where no reversible reaction is taking place between the components of the mixture of substances to be examined. If a reversible reaction takes place between the components of the mixture, allowance must be made for the effect of the solvent on the reversibility of the reaction and also for the effect of the numerous adsorptions and desorptions on possible equilibrium displacements. For example, in the reversible reaction between amino acids and glucose in the comparatively neutral range of pH 6 to pH 8, which may be conveniently represented as:

$$HR \rightleftharpoons H^+ + R^-$$
$$R^- + G \rightleftharpoons RG^-, \text{ and}$$
$$R^- + 2G \rightleftharpoons RGG^-$$

where HR is the amino acid, R^- is the amino acid-anion, and RG^- and RGG^- are the monoglucose and di-glucose complexes respectively, the use of acid solvents results in displacement of the reversible equilibria to the left, thus nullifying the interaction. Even the use of neutral solvents is unsatisfactory for investigation of the interaction, because the numerous adsorptions and desorptions are certain to result in further break up of the above complexes. However, paper chromatographic investigation of the amino acid-sugar interaction can be approached from the standpoint that the demonstration of the absence of a spot expected from the complex can be taken as evidence for the reversibility of the above reaction under specified conditions, e.g. the dilute amino acid-sugar aqueous solutions (Lewin 1958) in contradistinction to the highly concentrated 'solutions' involved in the semi-solid 'dry state'. (Gottschalk and Partridge, 1950).

Thus, the limitation of the chromatographic technique may be turned to advantage when properly interpreted. This approach is merely an illustration of the generalization that the exceptions to the rules are as important as the rules themselves.

On the *practical* side one may encounter considerable difficulty in ensuring strict standardization of the experimental conditions, even when all reasonable precautions have been taken. Assuming constancy of solvent, age, temperature, pH, absence of electrolytes, type of paper and its direction of mills' flow, there remain the unappreciated variations in technique from one laboratory to another which are often responsible for ununderstood experimental variations. One significant limitation is found even when technique variations are excluded. Multiple spot formations have been noted (for references see Zweig, 1959; Kellar and Giddings, 1960; Beckett, Beaven and Robinson, 1960) when pure substances have been used. These are attributable in some cases to chemical changes, separation of isomers or complex formation. Sometimes variation in the quantity of acid—other than that forming part of the solvent—associated with a given base results in the formation of multiple spots. Thus, Waldon-Edward (1954) noted with several basic amino acids and diamines that when one equivalent of sulphate was used two associated spots were formed, whereas more sulphate resulted in only one spot formation. West (1959) noted that the presence of certain acids resulted in the formation of two spots per base in the examination of certain amines. While these effects can be countered or allowed for in certain circumstances, they impose a significant limitation on paper chromatographic analysis of biological amino containing systems where strongly acidic metabolites are present, e.g. urine, because the effect of the concentration of such systems on multiple spot formation must be first clarified (Beckett, Beavan and Robinson, 1960).

Because of the minute quantities required, paper chromatography is an extremely useful tool. However it suffers from the disadvantage of a time lag. Several hours are usually required for a chromatographic run, and during that time the analysis cannot be known. This disability may be contrasted with the rapidity with which a pH measurement or an optical density determination is carried out. Centrifugal paper chromatography as well as the circular technique is capable of reducing the time interval. However no method is yet available in which paper chromatography can be carried out as rapidly as either of the above analytical procedures.

(*c*) *Ion Exchange*.—The use of ion exchange as an analytical tool is well established and the variety of materials available enables a considerable number of separations to be undertaken.

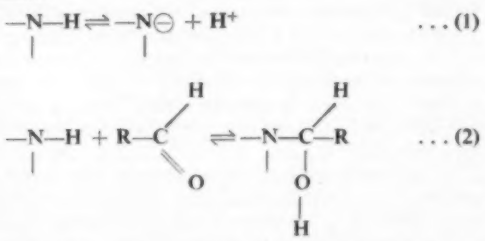
It is sometimes forgotten that a minimum number of regeneration and washing cycles is necessary to remove the smaller particles as well as extraneous matter occasionally present, and that slight but not negligible mechanical breakdown of the larger particles may give rise to finely divided particles. These small particles may pass through the sieves at the bottom of the column along with the 'pure' solution thereby enhancing 'experimental error'. Further, the active form of the ion-exchanger may not be stable, and so give rise to undesirable products. For that reason it is essential to check critically the presence of trace materials in the solutions which have passed through the ion-exchange columns. As an example one may quote the decomposition of ion-exchange material, containing quaternary ammonium groups which apparently (particularly after passage of aldehydic material) gives rise to amines.

The catalytic effects of ion-exchange resins are indeed appreciated nowadays, but it is necessary to remember

their undesirable effects equally well. For this reason it is essential to carry out control experiments to ensure that the existence of a certain substance in a solution which has passed through ion-exchange column is not necessarily due to its presence in the original solution but is rather a demonstration of its catalytic production from the constituents of the original solution on passage through the ion-exchange column. Such catalysis has been demonstrated in several cases, e.g. Rebenfeld and Pascu (1953) showed that glucose in contact with the strongly basic resin Amberlite IRA-400 was partly transformed into fructose, while fructose in contact with Amberlite IRA-400, was partly transformed into glucose. Each sugar was also partly transformed into organic acids.

The above possibilities of variations and errors emphasize the need for careful assessment of the limitations and suitability of the technique used for a given investigation. The difficulties arising out of such limitations are reduced when two or more tools are used in the study of a particular problem. Different tools are used in different laboratories in tackling individual problems, but unspecified differences in technique may exist and these may result in apparent variations. For this reason it would be more advantageous to carry out combined operations in the same laboratory.

The above difficulties may be illustrated as follows: The pH elevation technique introduced (Lewin 1957) can be used to detect and estimate the interaction of acid imino groups or sulphydryl groups with carbonyl compounds such as formaldehyde according to the scheme



... (1)

... (2)

This principle is also utilizable in the basic amino interaction with formaldehyde where a pH depression is obtained in the well known Sörensen titration.

As long as the pH range chosen is one in which equation (1) is operative, the absence of a pH elevation can, in absence of other over-riding considerations, be taken as evidence of the absence of an acid imino group. However, when the pH range concerned is outside that involved in equilibrium (1), say in regions over 5 pH units above or below the relevant pK value, the absence of a pH elevation cannot be taken as evidence for the absence of the imino group in these regions. This is because the pH elevation formulation depends on the ionization of the imino group, and the absence of this ionization makes it impossible to attain the pH elevation on formaldehyde addition. However, the limitation of the pH variation method in such pH regions can be met by the use of absorption spectra measurements. Absorption spectra curves of compounds containing imino groups are significantly changed on formaldehyde addition, and the change per mole of imino group is practically independent, under certain conditions, of the process of dissociation (Lewin 1961). Consequently, the effect may be used to demonstrate the presence of the imino group. A limitation is nevertheless encountered in that the measurements are best carried out at constant pH. When the solutions have but small buffering capacity, it is necessary to introduce a buffer which may affect the rate of attainment of equilibrium though not necessarily the equilibrium constants themselves. However, the combined use of the pH elevation method and absorption spectrum change usually results in complementary results which are in good agreement, thus resolving the individual uncertainties.

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Forthcoming Conferences

Gas Chromatography

The 4th International Symposium on Gas Chromatography, organized by the Analytical Chemical Division of the Gesellschaft Deutscher Chemiker and the Gas Chromatography Discussion Group of The Hydrocarbon Research Group of the Institute of Petroleum being also the 41st meeting of the European Federation of Chemical Engineering will be held at Hamburg (Germany) from June 13 to 16, 1962, inclusive.

The main language of the meeting will be English and the papers presented should be in a form similar to those at the former Symposia on Gas Chromatography, and will be classified under three headings:

1. Theory
2. Apparatus and Techniques
3. Applications.

Those papers concerning the application and the technique must have some novel feature to warrant their inclusion in the programme.

Preliminary registration for attending the symposium should be sent as soon as possible to the following address:

Gesellschaft Deutscher Chemiker,
c/o Dr. W. Fritsche,
Frankfurt/M,
Postfach 9075, Germany.

An early registration will help the Organization Committee, and is necessary for sending further information circulars and the final registration form.

ELECTRONICS FOR BIOLOGISTS

by G. C. Ware

Department of Bacteriology, University of Bristol

PART VI

Power Supplies

Valve amplifiers require low voltage power for their heaters, which for indirectly heated valves may be a.c., and for operation of the anode circuit a higher voltage, often between 100 V. and 500 V., which must be steady direct current. Batteries, though they form an ideal source of supply from the electrical point of view, are inconvenient, expensive and restrict the maximum power consumption and therefore the design of apparatus. Another source of d.c. suitable for the anode circuit must therefore be provided in every mains operated electronic device. Rectifying circuits may use either metal rectifiers or valve rectifiers. Only valve rectifiers will be considered here, these being generally better except at low voltages where metal rectifiers must be used.

The heater of a rectifier valve should be energized by

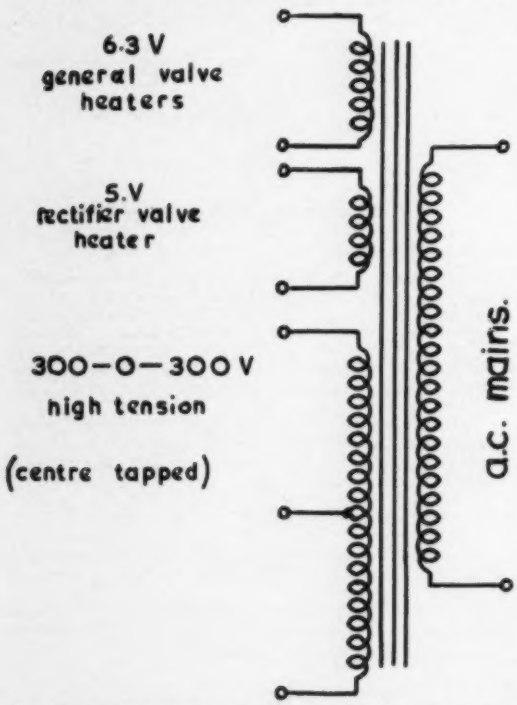


Fig. 38. A mains transformer for operation of electronic valve equipment, with three isolated secondary windings. The HT winding is centre tapped to allow for full wave rectification without recourse to a four rectifier bridge.

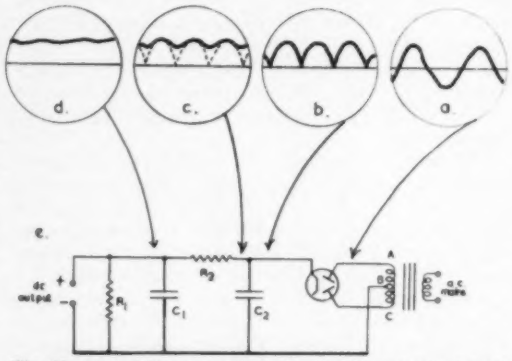


Fig. 39. (e) A full wave rectifier circuit using a centre tapped transformer and valve rectifier. (a) The original a.c. waveform (b) after rectification (assuming the filter circuit disconnected) (c) showing the effect of C_2 only (d) showing the effect of the complete circuit.

an electrically separate winding on the transformer to avoid possible interconnection between the high voltage section of the rectifier (cathode) and the heaters of the other valves. Commonly, then, a mains transformer will provide a well insulated heater circuit for the rectifier often of 5 or 6·3 V., another heater winding of 6·3 V. for the other valves, and the high tension winding of between 500 and 1,000 V. which for convenient full wave rectification must also be centre tapped (that is, divided into two equal and connected sections). (Fig. 38.)

A full wave rectifier valve contains two identical anodes, and a cathode which may be directly or indirectly heated. Fig. 39e shows a full wave rectifier circuit.

The rationale of the circuit may easily be established by following the only permissible flow of electrons, from negative cathode to the more positive anode through the valve, for the $\frac{1}{2}$ cycles when A is more positive than B and C more negative than B and then for the $\frac{1}{2}$ cycle when A is more negative and C more positive than B.

The output from a full wave rectifier, varying as it does between zero and maximum voltage in each $\frac{1}{2}$ cycle (Fig. 39e) is quite unsuitable for use in the anode circuit of an amplifier, and a filter circuit is necessary to *smooth* the output voltage. A large capacitor (C_2 Fig. 39d) connected to the rectifier output will quickly become charged to the maximum voltage and remain charged. Provided the capacitor is not discharged the voltage will remain steady at the maximum value. In practice however current is used, and the capacitor will discharge slightly during each cycle to produce a

voltage ripple similar to that shown in Fig. 39c. Further improvement may be achieved by a resistor (R_2) and second capacitor (C_1) which serves to by-pass the varying component of the voltage to earth retaining only the steady portion as in the case of a cathode by-pass capacitor. The resulting output (Fig. 39d) is sufficiently smooth for most valve applications.

This type of filter circuit is termed *resistance capacity smoothing* and is generally preferred for compactness and convenience. Losses do occur in the resistor however and some voltage drop is inevitable when current is being drawn. The final smoothed d.c. voltage is roughly equal to the input a.c. R.M.S. voltage from the transformer. When no current is being drawn the d.c. voltage will be equal to the peak a.c. voltage and the capacitors should be chosen to allow for this. The working output voltage may be adjusted by varying the resistor or alternatively, where several voltages are required, a resistance bridge may be constructed. Each resistor of the bridge must be of sufficient power handling capacity, and the total resistance should be high enough to avoid serious losses but low in comparison with the load to which it supplies current. Such a bridge is therefore always a compromise.

Very nasty shocks can be obtained from capacitors charged to high voltages and since they may retain their charge for considerable periods after the apparatus has been switched off a resistor (R_1 Fig. 39e) should be provided to discharge the capacitors, its resistance should be high enough to waste little current but low enough to cause fairly rapid discharge of the capacitors.

It has been shown (Part IV) that in a correctly connected

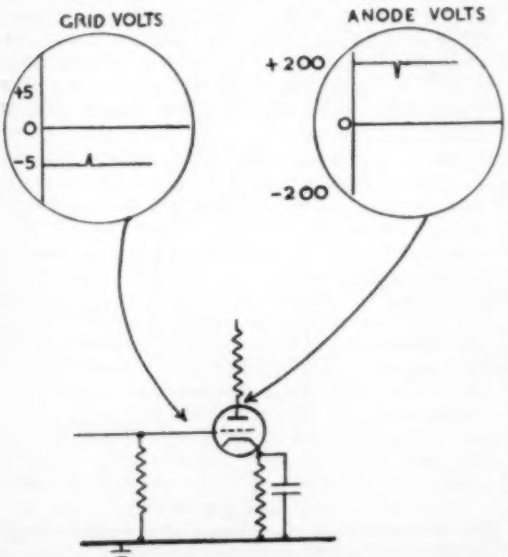


Fig. 40. An amplifier showing the effect of a small negative signal at the grid on the anode volts. Note the change of phase and increase of signal voltage.

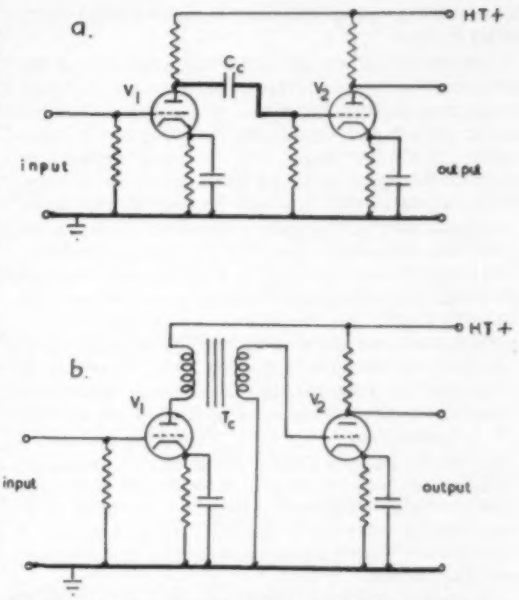


Fig. 41. (a) A two stage R.C. coupled amplifier consisting of two identical amplifiers. (b) The same amplifier using transformer coupling.

valve amplifier the current in the anode circuit, and therefore the voltage across the anode load, shows large changes for small changes in the grid voltage. In practice, the grid voltage change is a signal of some kind which is to be amplified, and provided all is well the amplified signal in the anode circuit will be a faithful reproduction of the original signal in all but one respect.

Because an *increase* in grid voltage is equivalent to reducing the resistance of the valve the anode *voltage* falls, and thus the polarity of the incoming and outgoing signals are reversed. This is termed a change of phase, the two signals being 180° (½ wave) out of phase. (Fig. 40). Although it is convenient to think of the signal voltages alone, it must always be remembered that these are in fact variations in, or superimposed upon, the steady electrode voltages of anode and grid. A 1 V. positive signal applied to a valve with a grid voltage of —5 V. might cause a reduction of anode volts from 200 to 150 V., a change of —50 V. This is often thought of simply as the amplification of a 1 V. signal to a 50 V. signal.

Amplifiers in Cascade

It is frequently impossible to obtain sufficient amplification with one valve to enable very small signals to be usefully used. All that is then required is to apply the already increased signal in the anode circuit of one valve to the grid of a second valve to produce an even larger signal in the second anode circuit and so on until the signal is large enough for use. Amplifiers so

connected are said to be in *cascade*, each amplifier being called a *stage*.

Because the grid of the second valve like that of the first, must be at its correct working voltage a direct connection between anode and grid is not permissible as the second grid would then be raised to the same voltage as the first anode. It is therefore necessary to separate the signal from the steady electrode voltage. With varying signals this may be done in two ways, and more simply by use of a capacitor which, as we have seen, will pass varying but block steady voltages. The coupling capacitor (C_c Fig. 41a) like any other will pass high frequencies better than low and must therefore be fairly large if low frequencies are not to be lost 0·1 μF is usually adequate. This method of coupling is called *resistance-capacity coupling* (R.C. coupling) to distinguish it from *transformer coupling* where the anode load resistor is replaced by the primary winding of a transformer (Fig. 41b). Variations in current through the primary induce voltages in the secondary which are applied to the grid of stage two. The steady anode current induces no voltage in the secondary so no isolating capacitor is required. No grid resistor is required for V_2 as the grid is connected to earth through the transformer.

Transformers have some advantages over R.C. coupling; they offer less resistance to the steady d.c. anode current and therefore introduce less H.T. voltage loss than an anode load resistor and may also be designed to provide a voltage increase resulting in further amplification between stages. Unfortunately, however, it is difficult and expensive to produce a transformer in which the output is a faithful reproduction of the input signal and moreover transformers introduce awkward phase changes in the signal. They are not therefore extensively used in amplifiers except for very high (radio frequencies) and in the input and output stages of multistage amplifiers where they can perform an important and special function.

Impedance Matching

Impedance, measured in ohms, is the resistance offered to a varying current, such as a signal or a.c., in the same way that resistance is offered to a steady d.c. As we have seen, the impedance of a capacitor is less towards a varying signal than towards a steady one but other circuits usually have greater a.c. impedance than d.c. resistance though with a simple resistor the difference is negligible. Impedance varies with frequency and must be quoted for a definite frequency.

It is a necessary condition for reasonable efficiency in electrically coupling two circuits that both should have similar impedances; at any rate, the impedance of the energizing circuit should not be much higher than the impedance of the energized circuit.

The output impedance of a valve between anode and cathode is very high (several thousand ohms) and it is often necessary to feed a signal originating in an anode circuit to a low impedance device; for example a

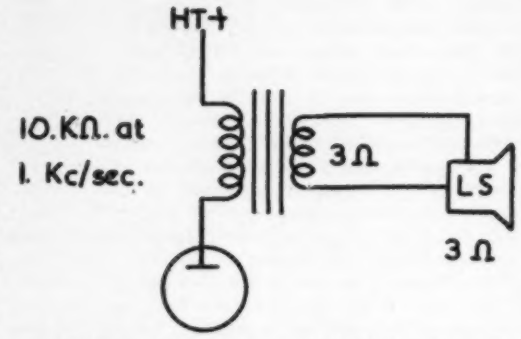


Fig. 42. Using a transformer to match the impedance of a valve to a loudspeaker. The d.c. resistances will be considerably less than the impedance at 1 Kc/s.

loudspeaker of 3Ω impedance. Direct coupling would in this case be very inefficient, and considerably better results are obtained by using an impedance matching transformer (Fig. 42). The transformer would ideally have a primary of the same impedance as the valve and a secondary of the same impedance as the loudspeaker. An ideal match is never obtainable in practice.

The Pentode Valve

Triode valves have some undesirable characteristics and in some applications the pentode may be more useful. It differs from the triode in having two additional grids but when correctly connected performs the same functions as a triode. As a rule, however, pentodes can give considerably more voltage gain per stage than triodes. Like triodes they too have undesirable qualities and to prevent these being cumulative in any multistage amplifier it is good practice to use a mixture of triodes and pentodes, the first and last valves being pentodes as

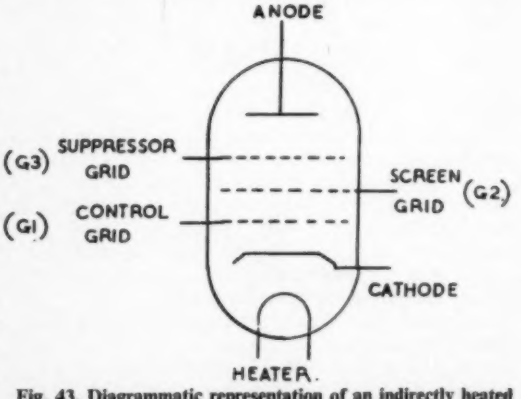
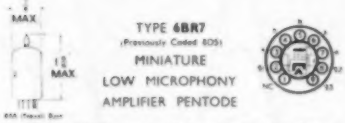


Fig. 43. Diagrammatic representation of an indirectly heated pentode valve. The grids are numbered in sequence away from the cathode and may be referred to by number or name. The control grid performs the functions of the grid of a triode. The cathode is omitted in a directly heated pentode where the heater also functions as the cathode.

TABLE IV



B9A (Nuvol Base

The BRIMAR type 6BR7 has been specially designed for use in the early stages of high gain A.F. amplifiers. Its thorough screening and rigid construction ensure low microphony and greatly reduced hum compared with existing types.

RATINGS

Heater Voltage	6.3 volts
Heater Current	2.15 amp.
Anode Voltage	300 volts max.
Anode Dissipation	0.75 watts max.
Screen (g_2) Voltage	125 volts max.
Screen Dissipation	0.3 watt max.

OPERATING CHARACTERISTICS

(g_3 connected to Cathode)

Anode Voltage	100	250	volts
Anode Current	2.0	2.1	mA
Screen Voltage	100	100	volts
Screen Current	0.7	0.6	mA
Control Grid (g_1) Voltage	-3	-3	volts
Anode Impedance	1.5	2.5	meg.
Mutual Conductance	1.1	1.25	mA/V

OPERATION AS RESISTANCE COUPLED AMPLIFIER

Anode and Screen Supply Voltage	100	200	300	volts
Anode Load Resistor	0.25	0.25	0.25	meg.
Screen Series Resistor	1.0	1.0	1.2	meg.
Cathode Bias Resistor	2,500	1,500	1,200	ohms
Peak Output	35	70	100	volts
Voltage gain	90	120	140	—

INTER-ELECTRODE CAPACITANCES

Input	6.0 pF
Output	6.0 pF
Control Grid to Anode	0.01 pF max.

When connected as a triode (g_2 to Cathode, g_3 to Anode), type 6BR7 has similar characteristics to those of type 6CSG.

Type 6BR7 is a commercial equivalent of the CV2135.

Part of the manufacturer's data sheet for Type 6BR7. *Courtesy Standard Telephones & Cables Ltd.*

they have particularly desirable characters as output valves and provide large voltage gain in the first stage to give a more easily handled signal.

In the pentode the electrode which performs the function of the triode grid, is called the *control grid* to distinguish it from the two additional electrodes (Fig. 43). One of these, the *suppressor grid* is invariably connected directly to the cathode. This is such a common connection that it is frequently made inside the valve at the time of manufacture. The second data sheet (Table IV) shows an exception where the suppressor grid has not been internally connected to the cathode. If the second extra electrode, the *screen grid*, or more simply the *screen*, is connected to the anode the valve will function exactly as a triode. For operation as a pentode the screen must be maintained at the voltage shown on the data sheet. This voltage is obtained from the H.T. line by a screen resistor the value of which may be given on the data sheet. When it is not given it may easily be calculated from the steady screen current. As the screen current varies in the same way as the anode current, signal voltage variations will be developed across the screen resistor just as across the anode load resistor or cathode resistor. A steady screen voltage is required so the screen signal must be by-passed to earth in the same way as the cathode signal. In this case, a higher voltage capacitor will be necessary but a smaller capacity will suffice and 0·1 μF. is usually adequate.

When the control grid voltage is obtained from a cathode resistor and the value for this is not given in the data sheet it may be calculated as for a triode, but it

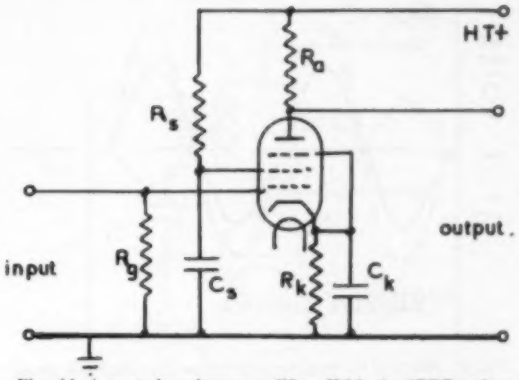


Fig. 44. A pentode voltage amplifier. With the 6BR7 and an HT supply voltage of 300V. the components should have the following values (see Table IV): $R_a = 250\,K\Omega$. $R_s = 1{\cdot}2\,M\Omega$. $R_g = 1{\cdot}0\,M\Omega$. $R_k = 1200\Omega$. **For good amplification at low frequency (down to 100 c/s) C_k should not be less than 25 μF and C_s 0·1 μF. The amplification of this circuit would be about 10 times that of the triode circuit in Fig. 29.**

must be remembered that in a pentode the cathode current is equal, not to the anode current, but to the sum of the anode and screen currents. Pentodes usually have rather higher anode impedance than triodes and so rather higher anode load resistors should be used.

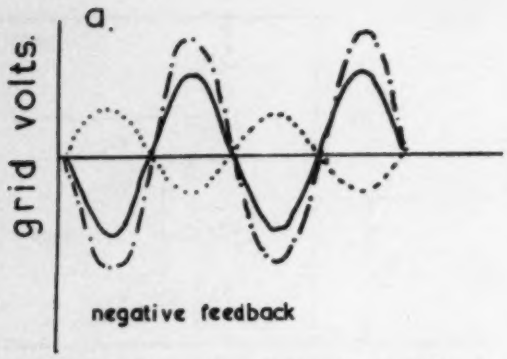
To summarize, pentodes provide higher amplification than triodes and require two additional circuit components, a screen resistor and capacitor. The suppressor grid must also be connected to the cathode if this is not done internally. Pentodes and triodes have other properties beyond the scope of this series. A complete circuit for a pentode amplifier is shown in Fig. 44 and should be compared with the triode amplifier Fig. 29. (May issue of *Laboratory Practice*.)

Oscillators and Feedback

It is possible, intentionally and unfortunately also unintentionally, to return part of the amplified signal from the anode circuit to the grid circuit thereby superimposing it upon the incoming signal. As was shown, one method of doing this is to omit the cathode by-pass capacitor in circuits where the grid voltage is being provided by a cathode resistor.

Although there is a definite time interval between application of a signal to the grid and a response in the anode circuit, this time is small and equal to the transit time of an electron between the cathode and anode (about 1/100 of a microsecond). Except with signals of very high frequency, where the time for one cycle approaches the transit time, it is permissible to regard the anode signal as simultaneous with the grid signal.

Consider the effect of returning directly a small part of the signal from anode to grid, either by a direct connection or by omission of the cathode by-pass capacitor. The returned signal, being 180° out of phase with the original signal will combine with and effectively



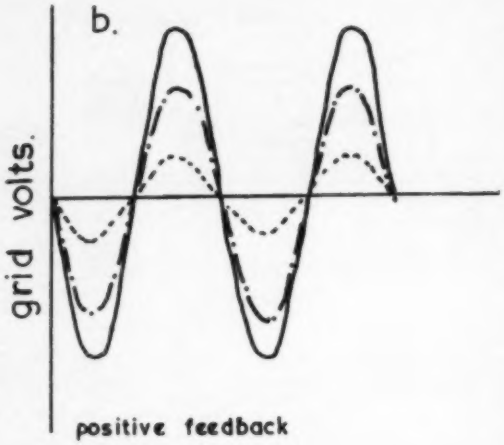


Fig. 45. Effect of (a) negative and (b) positive feedback on an original signal. — • — • — • original signal; - - - - - - feedback signal; ———— resultant signal.

reduce the amplitude of the incoming signal (Fig. 45a) producing a corresponding reduction of the amplified signal. This in turn reduces that fraction returned to the grid and produces a lessening of the reduction of grid signal and a consequent increase in output. The amplifier has therefore become partially self-compensating to any attempt to alter the input or output. We refer to a returned signal 180° out of phase as negative feedback. It serves well to stabilize an amplifier, though at the expense of amplification. Moreover any small noise such as hum or random changes in amplification which may be introduced by the valve circuit are at once reduced by return of a negative version of the spurious signal.

Suppose however the phase of the output signal was inverted by 180°, either by passing it through another amplifier or a specially designed circuit before being returned to the input, the returned signal would now be in phase with the input (Fig. 45b).

The resultant signal on the grid is now made larger by addition of the returned signal, with a corresponding increase in the output signal. In turn this causes an increase in the returned signal with a further increase in the input signal. The process will continue until the valve is supplying its maximum output. In practice no original signal is required in such a circuit and a small spontaneous impulse rapidly builds up to maximum amplitude. Positive feedback in small quantities therefore strengthens the signal but tends to result in instability, the amplifier becoming blocked. Small random noises and hum are also increased and positive feedback is therefore generally undesirable.

Tuned Oscillators

If a device is incorporated in a positive feedback circuit which is selective for one particular frequency then this frequency alone will be increasingly amplified and a pure signal obtained from the circuit. Such a signal generating circuit is called an oscillator.

Tuned Circuits

Combinations of coils (inductances) and capacitors can form circuits which have an infinite impedance to one particular frequency. As the frequency departs from that characteristic of the circuit the impedance rapidly falls.

A *tuned circuit* consisting of an inductance and capacitor is shown in the anode circuit of an amplifier (Fig. 46). The impedance of the tuned circuit will be high for one particular frequency depending on the actual values of L and C, and at this frequency the voltage drop across the tuned circuit will also be high. The tuned circuit acts as an anode load resistor and as a result the amplification will be greatest at the tuned frequency. At all other frequencies the impedance of the anode load will be low and no amplification of these frequencies will occur. If now a second coil is arranged so that voltage changes in L_1 can induce voltage changes in L_2, then by connecting L_2 to the valve input,

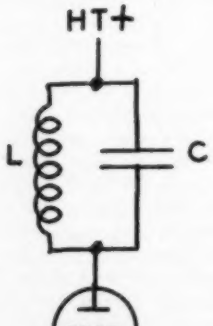


Fig. 46. A tuned circuit as an anode load. The values of L and C will determine the frequency at which the impedance is maximum.

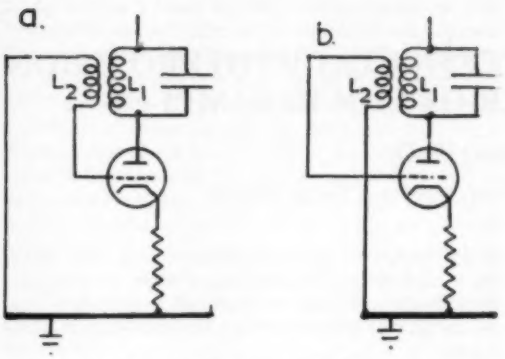


Fig. 47. (a) Positive and (b) negative feedback from a tuned anode load. The circuit providing positive feedback will oscillate at the tuned frequency.

part of the anode signal will be returned to the grid either in or out of phase depending on the method of connection (Fig. 47a and b). When connected in phase oscillation at the frequency of the tuned circuit will occur.

The tuned circuit may be placed in the grid or cathode circuit instead of the anode circuit. Grid voltage may be obtained from a cathode resistor as before, but in oscillator circuits the signal may become so large that the negative grid voltage is neutralized during part of the cycle and the grid becomes positive with respect to cathode. The positive grid will act like a second anode and current will flow from cathode to grid. If a capacitor is inserted in the grid circuit it will become charged by this current and restore a negative voltage to the grid and so stop the grid current. (Fig. 48). In oscillators a better sine wave is generally obtained by this system of controlling the grid voltage.

Valves as Switches

If the grid voltage of any valve is made sufficiently negative the effective resistance of the valve becomes so high that anode current virtually ceases to flow. In this condition the valve is said to be *cut off* and may be used as a switch, the load being connected in the anode circuit as usual. Increase of the grid voltage to a predetermined value allows the anode current to flow, operating the device represented by the load. Moreover the current may be regulated by altering the grid voltage. Switches of this type require no power to operate and can operate at very high speeds, the switching time being of the same order as the transit time (10^{-8}-10^{-9} sec.). A conventional mechanical switch may take appreciable power and time to operate. Quite small valves can be used to pass quite large currents, for instance a small electric light bulb or a small motor could be controlled by a 6L6 valve. The valve will of course act also as a rectifier the anode current being undirectional.

When a valve is operated with the anode current cut

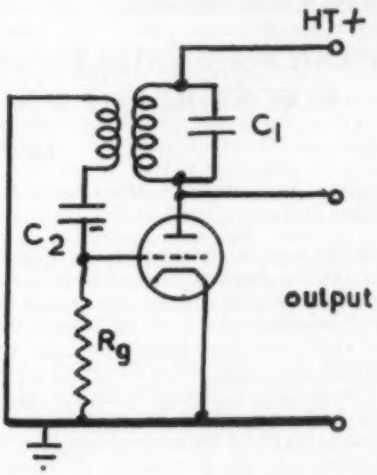


Fig. 48. The use of a capacitor in the grid circuit of an oscillator to ensure a grid voltage of 0 when large signals are probable. The cathode-grid section of the valve acts as a rectifier when the grid tends to become positive.

off the necessary grid voltage cannot be obtained from a cathode resistor, as no current is flowing in the cathode circuit. It must therefore be obtained from another source such as the bridge network described earlier. Where larger currents have to be switched than can commonly be handled directly by valves, electro-mechanical relays may be inserted in the anode circuits, but gas filled valves are available which are able to conduct much higher currents than normal vacuum types. The grids of gas filled valves negatively biased prevent the flow of an anode current. When the grid becomes positive a discharge occurs between cathode and anode and current flows. Unlike a vacuum valve restoration of a negative grid voltage does not exercise any control on the anode current, which continues until the anode voltage is removed or greatly reduced for long enough for the gas to become deionized (10^{-3} to 10^{-4} sec.). With 50 c/s. alternating current, the $\frac{1}{2}$ cycle during which the anode is negative is usually sufficient.

British Laboratory Ware

At a recent General Meeting of Members of the British Laboratory Ware Association Ltd., the following firms were elected to ordinary membership:

T. Gerrard & Co. Ltd.,
46/48 Pentonville Road,
London, N.1.

A. D. Wood, Esq.,
4 Skinner Street,
London, E.C.1.

Amal Ltd., of Holdford Road, Witton, Birmingham 6, and Deeley & Co. Ltd., of 1 George Street, Balsall Heath, Birmingham 12, were elected Associate Members.

APPARATUS AND DEVICES

AN EASILY ASSEMBLED AIR-THERMOSTAT WITH PROVISION FOR STIRRING A NUMBER OF LIQUID SAMPLES

by I. Bergman, Ph.D.

Safety in Mines Research Establishment, Ministry of Power, Sheffield

DURING work on the measurement of dissolution rates of fine powders, several suspensions had to be stirred at adjustable but controlled speeds and at a constant temperature over a period of weeks. When the samples were stirred from above by paddles, however, the solutions evaporated. When the sample bottles were partly immersed in a thermostat bath or jacket, the solution was concentrated by condensation of the solvent on to the lids of the bottles. These disadvantages were overcome by the construction of the apparatus shown in Fig. 1.

As very little heat was expected to be released or absorbed by the processes of dissolution, the stirring assembly (1) was incorporated into an air-thermostat consisting of the following easily obtainable components in a box (in our case a microscope cover with transparent panels): (2) a brushless motor hair drier, (3) a brick-shaped heat-exchanger from a car heater, (4) a small table fan, (5) a contact thermometer and (6) its control relay, and (7) a variable output transformer.

The hair drier, pointed downwards, was wired so that the fan was permanently on, and the heater filament was fed from the transformer *via* the relay. The heat exchanger, with tap water flowing through it, was used as a cooling unit at control temperatures less than 10C.° above ambient temperature. The additional fan was necessary to distribute evenly the heat generated by the motor used for stirring the samples, as this was necessarily close to the samples and below them. Small gaps in the box were found not to affect the operation of the thermostat adversely, though direct sunlight had

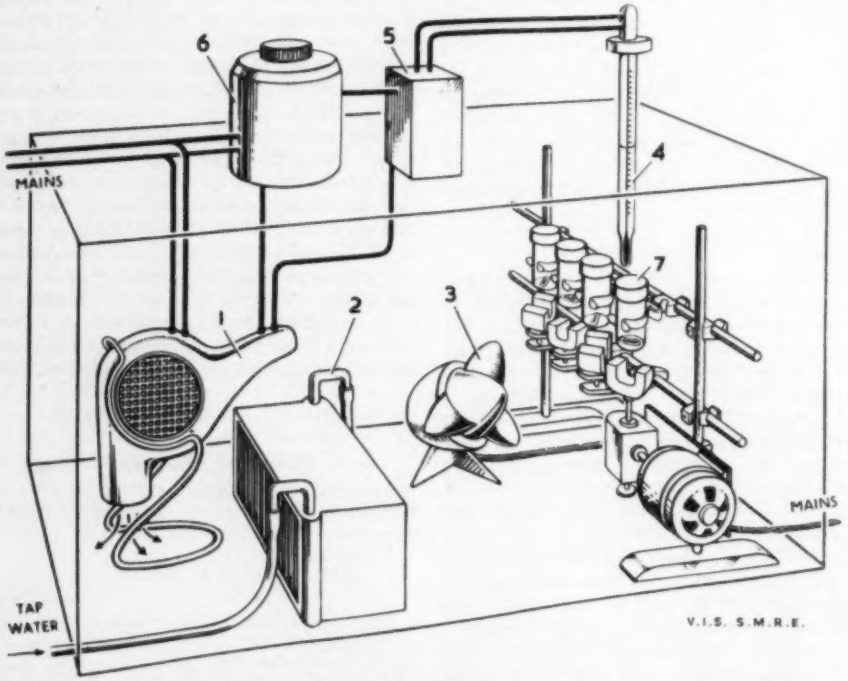


Fig. 1. Air-thermostat with provision for stirring a number of liquid samples. 1. Hair drier. 2. Heat exchanger. 3. Small table fan. 4. Contact thermometer. 5. Control relay. 6. Variable transformer. 7. Magnetic stirring assembly. *Crown copyright.*

to be excluded from the box during operation. The voltage fed to the heater of the hair drier was adjusted by means of the transformer so that the 'time-off/time-on' ratio was not larger than two or three. In fact at 25°C. and with a hair drier rated at 400 watts, a voltage one-third of mains voltage was found to result in a heating time of ten seconds and a cooling time of 20 seconds. As expected the thermostat worked well at temperatures in the range 30-50°C., but even at a control temperature as low as 25°C. and an ambient temperature of 22°C., the temperature at any particular point in the region of the samples varied by only ± 0·1C.° over a period of weeks. The temperatures over the major part of the box were within 0·3C.° of each other.

The samples to be stirred were contained in small polythene bottles held by spring clips. A polythene-covered magnetic stirring bar in each bottle was caused to rotate by a horseshoe magnet (approximately 2 in. × 1 in. × 1 in.) rotating beneath the bottle. Four magnets could be rotated continuously for months by one motor. One magnet was mounted at the end of a vertical motor shaft, while each of the other three was mounted on a vertical shaft rotating in ball races. The four magnets were set in line and with a minimum separation of about $\frac{1}{4}$ in. so that the interaction of their magnetic fields caused all the magnets to rotate when one of them was driven by the motor. A synchronous motor with continuously variable cone drive transmission was used for this purpose. A minimum speed of about 200 r.p.m. was needed for the magnets to synchronize with each other: if a much higher speed was required, say 1,000 r.p.m., it was necessary to synchronize the magnets at about 300 r.p.m. before increasing the speed gradually to the desired value.

Even at stirring speeds of 1,000 r.p.m. the temperature of aqueous solutions in sealed bottles was raised by only about 0·1C.° If the bottles were open, however, the solution temperature was found to be at least 0·5C.° below the control temperature, even when this was as low as 25°C. and beakers of water were placed in the box to raise the humidity.

A MODIFIED ANTI-COPROPHAGIC CUP

by B. H. Doell, M.Sc., A.R.I.C., and L. M. Bowler

Research Department Bovril Ltd., 148 *Old Street, London, E.C.*1.

Introduction

The rat practises coprophagy (eating of faeces) even when caged on a wire mesh grid. This is a matter of some importance as the results of rat experiments are so often applied to human nutrition.

A successful tail-fixing cup to prevent coprophagy was described by Barnes *et al.* (1957). With the aid of this device the effects of the ingestion of faeces on the nutritional needs of the rat have been studied.

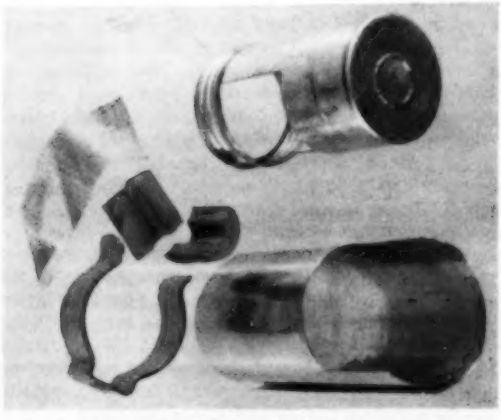


Fig. 1. Components of the modified anti-coprophagic cup.

The device consisted of a polythene cup which fitted over the rat's tail root and anus and which was protected from the animal's teeth by brass shim metal and covered overall by a length of wide rubber tubing (cycle inner tube). The cup was held in position by a piece of felt fixed by skin adhesive and a piece of adhesive tape.

Although, in our experience, the device traps faeces satisfactorily, certain difficulties have been encountered. Occasionally cups slipped off or were removed when the animal gnawed away the rubber sleeve and the retaining adhesive tape. More often, repeated removal of the tape to empty the cup caused serious damage to the tail.

An all-metal cup has been devised which is proof against the rat's teeth and accidental removal, and which can be emptied without removal from the animal. In addition the device is lighter than the Barnes cup.

Materials and Manufacture

Cup.—This is made from a 55 × 27 mm. spun aluminium, screw-capped tube (Metal Box Co. Ltd.). A $\frac{1}{8}$ in. hole is drilled in the closed end and enlarged by reaming with a centre punch to give a hole large enough to take the rat's tail, and with smooth round edges. A window 1 in. square is cut in the side by making two parallel transverse cuts with a hacksaw and removing the isolated metal by bending in and out when parallel fractures complete the square. The threaded end of the tube is bent over to give a round surface. All rough edges are smoothed off (Fig. 1).

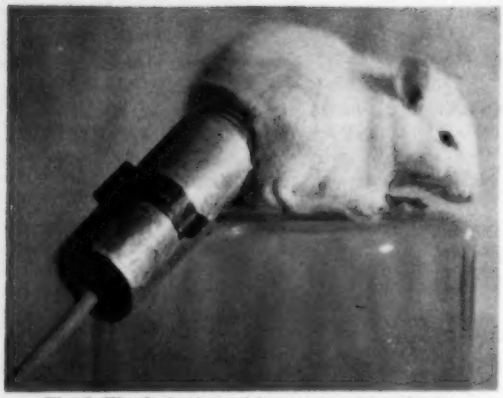


Fig. 2. The device in position on a young male rat.

Outer sleeve.—The outer sleeve consists of a 4 in. × 2½ in. piece of aluminium sheet (30 S.W.G., 0·013 in.) with a 1 in. square window cut in one edge. By suitable positioning the inner window can be closed to trap faeces, opened to empty the device, or left open to provide 'controls'.

Clip.—'Terry' clip No. 81/3.

Rubber stops.—These consist of pieces of pressure tubing ½ in. long, $\frac{3}{16}$ in. bore, $\frac{5}{32}$ in. wall, cut longitudinally into two pieces, each slightly less than half a cylinder. Vertical edges that are to bear on the rat's tail are cut flat.

Adhesive.—Evo-stik 'Impact' household adhesive (Evode Ltd.).

Adhesive tape.—½ in. × 1½ in. strips of zinc oxide plaster B.P.C.

Fixing the cup.—The rat's tail and the inner side of two rubber stops are smeared with adhesive and allowed to dry for about 15 minutes. It is sometimes necessary to apply a second coat of adhesive to the tail. The tail is threaded through the cup, which is pressed against the rat's body. The prepared rubber stops are then pressed firmly against the rat's tail close against the aluminium cup, and a strip of adhesive tape bound lightly round them. The aluminium sleeve is slipped over the cup and clipped in place with a 'Terry' clip (Fig. 2). Should the device become loose due to the rubber stop moving slightly before the adhesive had finally set or because the rat's tail has grown, then a tight fit can be restored by inserting additional stops, of suitable length, between the original one and the cup. Male rats of about 100 g. weight have been mainly used in our experiments and in animals of this size the scrotum is included inside the cup. The device works equally well with female rats.

Our experiments are usually of two weeks duration and the cups have been kept in position without failure for this period on over 100 animals. Only one sore tail has been encountered. There seems to be no reason why much longer periods should not be possible.

The device is large enough to contain all the faeces passed during a weekend.

Housing animals.—Animals used in coprophagy experiments are most conveniently housed in cages from which the wire screen had been removed. A double sheet of filter paper is placed on the bottom of the cage and covered with a well-fitting sheet of perforated zinc. This procedure had the advantages that urine is soaked up rapidly by the filter paper and the latter is protected from the rat's teeth.

Name.—'Anti-coprophagic cup' is not a particularly convenient name. A more suitable and acceptable possibility is 'faecollector'.

REFERENCE

Barnes, R. H., Fiala, G., McGehee, B. and Brown, A. (1957). J. Nutr., 63, 489.

A Simple Pipette for the Transfer of Small Quantities of Mercury

by D. C. Cornish, Ph.D.

Department of Chemistry, British Scientific Instrument Research Association, Chislehurst, Kent

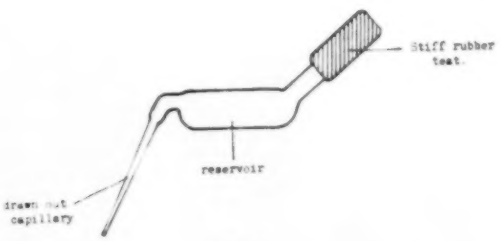


Fig. 1.

THE filling of mercury contact tubes from a beaker or by means of a drawn-out pipette is frequently difficult to accomplish without spilling. The pipette illustrated in Fig. 1 enables the transfer of small quantities to be carried out without this danger.

The pipette is filled by sucking mercury into the reservoir from a small beaker. It is necessary to squeeze the rubber teat several times to achieve this, and the capillary inlet is then emptied by gentle pressure before the pipette is removed from the beaker. Delivery of the mercury is carried out by tilting the pipette so as to fill the neck and then squeezing the bulb until the required quantity has been expelled. With careful tilting and manipulation the delivery can be controlled in a dropwise manner. If a larger teat is used the pipette can be scaled-up for use with larger quantities.

REPORT

GLASS TECHNOLOGY FOR EXPERIMENTAL GLASSBLOWERS

THE eleventh one-day Colloquium on Glass Technology for Experimental Glassblowers was held by the Ministry of Aviation in London on Wednesday, April 19. By kind permission of Sir Christopher Ingold, F.R.S., the colloquium was held in the Chemistry Department, University College, Gower Street, London, W.C.1.

The following programme had been arranged by Mr. I. C. P. Smith, B.Sc., F.S.G.T.:

'Burners for Glassblowers' by Mr. N. Payne of I.C.I. Plastics Ltd.

'Sintered Filters' by Mr. I. C. P. Smith, B.Sc., F.S.G.T. of E.R.D.E.

'Molecular Stills' by Mr. P. Ridgeway Watt of the Walton Oaks Experimental Station of Vitamins Ltd.

Mr. Payne started his talk by briefly referring to the earlier records of lampworking of glass in the 18th century. The source of heat was an oil lamp with a jet of air directed across it to provide a flame whose size and direction could be varied according to the size of the jet, its placing relative to the flame, and the pressure of air supplied. The air supply came from the operation of a large pair of leather bellows of a similar kind to those still in use by some farriers. The practice of blowing a jet of air across or through a luminous flame was still used by bench glassblowers until recent times. The next development was the burning of the gas at the end of a tube, and feeding the air into the flame from a smaller tube placed inside and concentric with the gas tube. This produced the well-known blast burner or cannon burner, this burner and its variants was still the most commonly used burner for bench glassworking. These burners were satisfactory for the working of the soda-lime or 'soft' glasses, but in recent years there had been a great increase in the use of the borosilicate glasses, and therefore the need to increase the flame temperature by adding oxygen to the air supply of the burner. This type of burner was capable of providing a very wide range of flame sizes, and although for some sizes the flame produced might be somewhat ragged, it covered practically the whole of the range necessary for normal working, only needing to be supplemented very occasionally by a special burner for a specific operation. The great disadvantage of this type of burner was the noise it made when oxygen was added to its air supply and if several of these burners were being used together the noise became unbearable. Many people had therefore attempted to design a silent or nearly silent burner. There has been in existence for a long time a near silent type of burner of the premix type. In this burner the gas and oxygen or air are premixed in a mixing chamber and then led to the burner, which is constructed with a large number of small holes or a grill. The gas burns quietly and at a high temperature on this grill. This type of burner provides good flame characteristics, but is inflexible as the flame can only be altered between very narrow limits. Another type of burner which gives a nearly silent flame is the surface combustion burner, in this type of burner the nozzle consists of a multiplicity of small orifices at which a mixture burns fairly quietly with a hot flame. It is difficult to design means of readily adjusting the flame size on this type of burner, and it is also extravagant in consumption of oxygen.

The usual way of attempting to combine the virtues of the premix burner and the cannon fire is to have a premixer connected to a rotatable turret, on which is mounted a range of jets so that the size of the flames produced can be widely varied. Mr. Payne then demonstrated in turn a blast burner of a type which was familiar to all the members of the audience, and then six different burners of the premix type each embodying the rotating turret principle, offering useful comments and opinions on each one. Briefly mentioning burners for glassworking lathes, and describing some recent developments in this field, he concluded his talk by reminding the audience that the potential market for bench burners for glassblowing was relatively small. Therefore it was unreasonable to expect burner manufacturers to carry out a great deal of research in such a field where they had very little chance of recouping their costs. It was up to glassblowers themselves to carry out development work to design and produce a prototype burner which would satisfy their needs, then to find a burner manufacturer who would produce it at an economic price.

A very lively and protracted discussion then ensued in which a large number of the audience took part.

Mr. I. C. P. Smith made some good points about the design of burners, The desirability of the correct internal profiles of the jets to ensure a smooth stable flame, and the provision of really suitable control valves for the gases were two items mentioned.

A great deal of discussion centred around the noise problem, one speaker reporting he had become completely deaf in one ear through using a blast burner over a long period, and several others reported partial loss of hearing. Much could be done to reduce the effects of the noise by suitable acoustic linings to the glassblowing workshop, but it was generally agreed that the real solution lay in reducing the noise at the source by the use of silent or nearly silent burners. Other topics discussed were burners of American origin; one member of the audience produced one made in the U.S.A. and said he found it very satisfactory in use. The use of both coal and natural gas at a much higher pressure in U.S.A. could explain the failure of some American

burners to come up to the performance expected of them for some were designed to work at gas pressures as high as 5 lb. per square inch.

Sintered Filters

In his talk on sintered filters Mr. Smith gave a very thorough review of the whole field of sintered glass filters. He started his talk by showing some photomicrographs of the glass powders used in the production of the filters. He then showed how the ratio of the aperture or pore size of the filter to the grain size could be calculated and how the sieve sizes necessary to produce a given grain size could be worked out. A detailed description of the apparatus used for grinding the glass to powder was then given. This apparatus consisted of a specially designed ball mill in which the lumps of glass to be ground were placed. It is extremely important that the properties of the finished discs should match the parent glass very closely as they have to be sealed into tubes and moulded forms. If there is a mismatch between them then great difficulty will arise in the annealing process and it may well prove impossible to prevent cracking of the sealed in discs. Dried air is passed through the mill and is also used to elutriate the powder. The air is then recycled through the apparatus, this dried air being necessary to prevent clogging and adhesion of the finer particles. The humidity of the air must be controlled, for if the glass particles are absolutely dry then trouble is experienced with electrostatic effects. The mechanics of the sintering process were then explained. The object of the process was to obtain adequate adhesion between the particles without overmelting producing 'necking' between them. Sintering at too high a temperature or for too long a time can lead to overmelting, 'necking' and a consequent reduction in the ratio of pore size to grain size, and therefore of the porosity of the finished disc. Various materials had been used as moulds to contain the glass powder, such as stainless steel, fused silica, and special metal alloys. Some release agent has always to be used between the filter and the mould. The behaviour of the powder during sintering varies according to its grain size, coarse powders expanding and finer ones shrinking.

With the very fine filters of number 5 porosity, it is usual to make up a composite filter consisting of number 5 sintered on to a number 3. The number 3 provides the mechanical support for number 5, which would not be strong enough to withstand atmospheric pressure when evacuated on one side. The production of these fine filters (number 5 has a pore size of up to 2μ) poses special problems. The fine powder is mixed with some organic medium which will burn out in sintering. The mixture is first evacuated to remove bubbles, then spread evenly as a paste on the number 3, which has been partially sintered previously. The final firing operation must be carried out extremely carefully. Mr. Smith also described the methods of production of special filters such as curved filters used in large diameter Buchner funnels and thimble type filters. He also briefly described the methods of manufacture of sintered ceramic filters and sintered metal filters.

Molecular Stills

Mr. Ridgeway Watt explained that many compounds which have high molecular weights say up to about 1,000, and boil at relatively high temperatures in the pressure range of 20 to 760 mm. Hg., are so susceptible to decomposition when heated that they cannot be distilled successfully. The only means of distilling them is to reduce the operating temperature to a relatively low figure, by reducing the pressure in the still to a very low value of about 10^{-4} mm. Hg. When the pressure above a substance is of this order phenomena different from orthodox boiling appear. Ebullition, in which bubbles of vapour are evolved from the body of a liquid, does not occur. If the mean free path of a molecule in the vapour is greater than the distance between the evaporating and condensing surfaces, and if molecules which strike the condensing surface do not rebound and are not re-evaporated, then any molecule which leaves the heated surface cannot return. If the evaporating and condensing surfaces are sufficiently close together, the separation of mixtures can be effected at these low pressures by evaporative processes. The different molecules leave the hot liquid surface at rates depending on their relative molecular weights and vapour pressures. This is called molecular distillation, and using these methods vitamin A concentrates and high boiling petroleum fractions have been successfully distilled.

There are four different types of molecular still, the pot still, falling film, centrifugal and wiped film. The pot still is historically the first and simplest in construction. In practice a separation approaching the theoretical value is difficult to attain because the liquid surface becomes depleted in the more volatile component. If the distilland is spread out into a thin film this effect is minimized, the thin film may be obtained by allowing the material to flow under gravity, for example Taylor [1] has described such a falling film still. Hickman [2] has used centrifugal forces to spread the film. The latest development in molecular stills is the wiped film type, and in the speaker's opinion this type had completely superseded the falling film type. Mr. Ridgeway Watt then described a semi-micro molecular pot still with a range of 0·2 to 5 grams of distilland which was not novel in principle but had an interesting arrangement [3]. He then showed the parts of a complete still of the wiper type, and described with the aid of slides its construction and operation. In this type of still, the evaporator rotates while the condenser consists of a static assembly of five truncated metal cones running co-axially down the centre of the evaporator [4].

REFERENCES

[1] Taylor. (1946). J. Res. Nat. Bur. Standards, 37, 173.
[2] Hickman. (1944). Chem. Reviews, 34, 51.
[3] Ridgeway Watt. (1960). Chem. Ind., 713.
[4] Ridgeway Watt. (1960). Chem. Ind., 1207.

BOOK REVIEWS

XVIIth International Congress of Pure and Applied Chemistry, Munich 1959; Volume I, Inorganic Chemistry. London: Butterworths. Weinheim: Verlag Chemie GmbH. 1960. pp. 341. 63s.

The main subject of this Congress was inorganic chemistry and in this volume the plenary lectures and the main subject lectures on this topic are collected together. The period since the war has seen a resurgence of interest in preparative inorganic chemistry, stimulated by the wide availability of powerful physical methods of structure determination, such as infra-red and nuclear magnetic resonance spectroscopy, and the desire to test the predictions of valency theory. Organometallic compounds, hydrides and fluorine compounds are the subject of much current synthetic work; reactions in non-aqueous solvents are increasingly exploited. In addition the actinide elements have become available, ultraviolet and mass spectroscopy have greatly extended the scope of investigations of the species present in gases at high temperatures, and solid state studies have awakened interest in the preparation of extremely pure metals and compounds. The 19 papers of this volume give an excellent conspectus of work in these fields occurring throughout the world. Of course, the whole of inorganic chemistry is not represented; for instance, those primarily interested in the study of complex ions or in analysis will need to look elsewhere. The book is very well produced.—J. E. PRUE.

Organometallic Chemistry (ACS Monograph No. 147), edited by H. Zeiss, New York: Reinhold; London: Chapman and Hall. 1961. pp. xiv + 549. 140s.

It is made clear in the preface to this book, if not in the title, that it is not a comprehensive survey of organometallic chemistry. It is a series of summaries on a variety of topics involving organometallic compounds. Often these topics are quite unconnected with the remainder; indeed, in the fascinating contribution by R. Huisgen on 'Benzyne Chemistry' the role of the organometallics is secondary. In the other nine sections, J. W. Richardson discusses 'Carbon-metal bonding'; H. D. Kaesz and F. G. A. Stone, 'Vinylmetallics'; H. C. Brown, 'Organoboranes'; K. Ziegler, 'Organoaluminium compounds'; H. Gilman and H. J. S. Winkler, 'Organosilyl and organogermyl compounds'; P. L. Pauson, 'Cyclopentadienyl-metal compounds'; H. Zeiss, 'Arene complexes of the Transition metals'; G. E. Coates and F. Glockling, 'Transition metal alkyls and aryls' and J. Chatt, P. L. Pauson and L. M. Venanzi 'Metal carbonyls and related compounds'.

All these sections represent topics of great current interest; all are well done and are, moreover, readable accounts of the subjects chosen. One emphasis is laid on discussion of reaction mechanisms and structural implications so that the tendency which many monographs show towards being mere collections of reaction data is not apparent with this work. The book can be recommended to all chemists whether working in this field or not as an excellent summary of modern trends. It is, however, a great pity that the subject index is so poor; it is much shorter than the Table of Contents and does not fulfil the purpose for which indexes are compiled. Editors and publishers have a duty to provide an adequate index, especially in high-priced books; in this case that duty has been neglected.—G. M. DYSON.

The Technique of Photomicrography, by Douglas F. Lawson, F.I.B.P., F.R.P.S., F.R.M.S., F.Z.S. London: George Newnes Ltd. 1960. pp. 256 + xvi. 55s.

It is not many years since photomicrography was practised by only a few scientific experts and a small number of enthusiastic amateurs using their ordinary equipment plus their home-made gadgets for connecting camera and microscope together. Now almost every research laboratory uses photography for producing permanent records with the microscope, and specialized equipment may be purchased ranging in cost from less than a hundred pounds to thousands of pounds.

The work turned out by these establishments is however in many cases poor or indifferent to bad. This is no doubt due in many cases either to the microscopist having no real knowledge of photography, or the photographer having a very limited knowledge of the optics of the microscope. In my opinion, Mr. Lawson's book should prove of great value in helping to correct this state of affairs.

The work consists of a foreword by Dr. John Farquharson, F.R.I.C., Managing Director of Beechams Research Laboratories Ltd., a Preface by the author, 14 sections on the microscope, camera, and various techniques and also a section on mounting and staining, with a glossary of terms and a very useful bibliography

Mr. Lawson introduces his subject with a section on photomacrography which bridges the gap between straightforward photography and photomicrography. Here much useful advice is given on inexpensive equipment. When dealing with more expensive apparatus, however, no mention is made of the Leica reflex housing with bellows which is capable of giving up to six times magnification, and is a very useful piece of equipment. A great deal of information is given on illumination, filters and sensitive materials. There is also described a method for macrophotography by projection, and details are given of a method of illumination for translucent material designed by the author.

Sections 3, 4 and 5 deal with the various parts of the microscope, together with its care and maintenance, and form a most valuable part of the book. However, the reviewer is not happy with the suggestion that a centering mount for the substage condenser can be omitted. It is true that for a lot of work it is unnecessary, while the illustrations prove the author's point that he can do without one, but few if any of the leading

instrument manufacturers would now supply an achromatic condenser without such a mount. A great deal of the most practical information is given on microscopic optics, the condenser system being given a section to itself, and very rightly so, since it is in the correct use of this part of the microscope that so many workers fail.

Four sections are devoted to the subject of illumination. A number of illuminants, including electronic flash and infra red are described in detail, with notes on their advantages and disadvantages, and information is given on dark field work, the use of filters and phase contrast and interference microscopy.

Further sections cover various types of camera equipment, stereoscopic photomicrography, and the use of flashlight photomicrography. The photographic processes, including colour, are briefly described and cover a number of the well-known manufacturers' products.

An outstanding feature of the work is the profuseness and diversity of the illustrations, the value of which is even further enhanced by the technical data appended.

Mr. Lawson's book is indeed a most valuable addition to the literature for the photomicroscopist.—NORMAN GRUBER.

Tools of Biological Research (Second Series), edited by Hedley J. B. Atkins, D.M., M.Ch.Oxf., F.R.C.S.Eng., Hon.F.A.C.S. Oxford: Blackwell Scientific Publications 1960. pp. 175 + xii. 37s. 6d.

The Second Symposium on 'Tools of Biological Research' given before members of the Surgical Research Society has been permanently recorded in this volume. The additional techniques treated therein comprise: Electron Spin Resonance Spectroscopy, Electroencephalography, Paper Chromatography, the Ultracentrifuge, X-Rays, Fluorescent Antibody Techniques, Phonocardiography, Vectorcardiography, the Cathode Ray Oscillograph (particularly in Electromyography) and Microradiography.

Postgraduate workers in many biological fields besides surgery will find much of interest in this compilation. Several of the techniques, indeed, are more likely to be useful to the biochemist or physiologist than the surgeon.

The ten specialist authors have, without exception, produced first rate introductions to their subjects. Explanations, illustrations and examples of the practical application of the methods are clear, unambiguous and devoid of unnecessary frills. References are generally not exhaustive but appear to be well selected as a guide to deeper understanding of the specific techniques.

The unobstrusive hand of the editor is sensed in the uniformly high quality of the entire work. Only one typographical error was noticed (p. vii, l.7) wherein the editor makes a rather pleasant, though doubtless unintentional, pun when acknowledging financial assistance from the 'Welcome' Trust!

Although one feels that the price is somewhat high for a book of this size, the printing, the paper and the informational contents are of such excellence that the project is well worth while for, apart from items of specific practical applicability, such anthologies of science provide inspiration, stimulate co-operation between workers in different sciences and also help to counteract the stultifying effects of narrow specialization.—G. F. H. WHITNEY.

Biochemistry of Steroids, by Erich Heftmann and Erich Mosettig. New York: Reinhold Publishing Corporation, London: Chapman and Hall Ltd. 1960. pp. 231 + xi. 55s.

This volume, which comes from the same publishing house as the Fieser's 'Steroids', is intended to cover the main aspects of the biochemistry of the steroids without the limitations of detailed and academic steroid chemistry. The authors have sought to provide a readable text for workers in allied sciences whose subjects impinge on the steroid field and to achieve simplicity and comprehensibility have presented the material in unorthodox form. References, names of authors, tables, diagrams and footnotes have been kept to a minimum in order to bring flow-sheets and formulae into close juxta-position with pertinent text. To off-set the lack of text references an excellent modern bibliography provides, chapter by chapter, reading for the student and the specialist; this bibliography runs to 45 pages and is a major feature of the book.

The sequence of chapters is unexpected and the claim that the arrangement promotes understanding of the biogenetic relationships can only be justified to a limited extent. Adherence to a standard form in the presentation of comparable chapters has made for easy understanding and has improved the value of the book for reference. The chapters on the steroid sapogenins and the cardiac glycosides make a noteworthy contribution to a book which maintains a high standard throughout. Possibly because of the many specialists who have reviewed sections of the manuscript, the text is factual and reliable and the print singularly free of typographical errors. The book can be recommended and may be bought by newcomers to the steroid field but it is likely to be retained by many others as a convenient source of reference and as a guide to the literature.—A. E. KELLIE.

Separation and Identification of Food Colours permitted by the Colouring Matters in Food Regulations 1957. London: The Association of Public Analysts. 1960. pp. vi + 31. 21s.

The Association of Public Analysts was rightly concerned about the identification of colours permitted under the Colouring Matters in Food Regulations and appointed a Committee to enquire into the best methods of ensuring that the Regulations could be properly enforced. The results of the work of this Committee are embodied in a small report which gives working details

for those laboratories not entirely conversant with the extraction of a colour from a food or with its subsequent identification.

Normally the Public Analyst is not concerned as much with the actual identification of a prohibited colour in a food as he is with ensuring that any colour is a permitted one as distinct from a non-permitted one, but it is practically impossible to achieve the latter without carrying out the former. Fundamentally the technique followed is that of obtaining a solution of the colour with as little interfering material from the food as possible, e.g. starch or protein, extraction of the colour from this solution on to wool in acid, or alkaline solution, stripping with weak ammonia or acid, purifying by paper chromatography, and then, if necessary, carrying out further tests, such as examination under ultra-violet light, the effects of dilute or strong acids and alkalis and when essential, examining a solution of the colour using an ultra-violet absorption spectrophotometer.

Guidance is given so that natural impurities in the colours are not reported as prohibited colours. This is a most important point to be stressed.—T. McLACHLAN.

Annual Reports on the Progress of Chemistry for 1959, Vol. LVI. London: The Chemical Society. 1960. pp. 476 + vi. £2.

In some measure one experiences a sense of awe when preparing to review this work. Here, in relatively few pages, is contained the pure distillate of one year's chemical efforts brought together by 32 chemists who have explored, rejected and accepted the chemical literature of the world for 1959. It is recognized that our experts must, for reasons of space, limit the scope of their annual reviews which may not therefore be wholly comprehensive. Nevertheless to gain some small idea of where the world is going in the science of chemistry, it was considered of interest to compare these present Reports with their counterparts of 20 years ago.

The Reports for 1939 had something to say on Radioactivity and Sub-Atomic Phenomena. Mention is made of the discovery of an outstanding feature 'nuclear fission' with the possibility of liberation of energy 'on a large scale'. In 1959 the Report Radiation Chemistry covers the radiolysis of liquids and gases, saturated hydrocarbons having received special attention in this field. The section General and Physical Chemistry was in 1939 concerned with structure and molecular forces in liquids, chemical kinetics and surface chemistry. An excellently written Report for 1959, Electrochemistry, treats of our much fuller understanding today of ion hydration in solution. Reaction kinetics are still of interest in the present work with, needless to say, abundant mention of the now universally accepted free radical. New techniques now permit the study of certain very fast steps in chemical reactions. Under Inorganic Chemistry in 1939 such items as the higher fluorides of carbon, iodides of some of the then rarer elements (tantalum, columbiun, titanium and vanadium), extensive studies on the rare earth elements and reactions in non-aqueous solutions made the news. The present Reports treat, under this section, the numerous organo-metallic compounds recently studied and present knowledge of structure in inorganic chemistry, e.g. sulphate ion contains two types of S-O bond and calcium carbide contains an acetylide ion. Many new compounds of the transition elements have recently been prepared and interest is still shown in reactions in non-aqueous solutions.

What of organic chemistry in the past 20 years? Reaction mechanisms were much discussed in 1939, an understanding of the Hofmann, Lossen and Curtis Rearrangements being sought and the peroxide effect being much studied in the reactions of various chemicals with olefinic and acetylinic groups. In 1959 Electrophilic Aromatic Substitution has been reviewed as has the evidence for the existence of the carbonium ions. In this connection mention is made of the need to differentiate between the property of an ionizing solvent to assist ionization and its property to sustain dissociation. Stereochemistry discusses systems of nomenclature for optically active compounds and mentions the need for organic chemists to go one stage further into physical chemistry and to consider entropy as well as energy of activation. As the alicyclic compounds become the more studied one wonders whether it is not high time for all chemists to represent the benzene ring with double bonds in order to avoid its confusion in formulae with cyclohexone. Alkaloids and Carbohydrates provide lasting problems for study, with the latter mention being made of the increasing biological importance of the amino-sugars.

Biochemistry in 1939 was swamped with papers on vitamins and nutrition. The conversion of β-carotene to Vitamin A in the body is still in 1959 not fully understood. A reawakening of interest in the chemistry of the mineralized tissues during the past decade provides the reason for the present section on the chemistry of bone and tooth materials. Other sections deal with muscle-contraction and new amino- and imino-acids obtained from plants. Finally Analytical Chemistry which in 1939 dealt with chemical microscopy, the analysis of dusts and smokes and the rebirth of the now widespread technique of chromatography. Over the past 20 years there have of course been profound advances in techniques and reagents in analytical chemistry. The 1959 Reviews mention the need for instrumental methods always to be based on chemical reactions which are fully understood since instrument readings can be completely misleading. Words of wisdom indeed. A reading of this section emphasizes the need for all chemists concerned with analysis to make sure their techniques are not ancient by present-day methods.

One must end as begun with high praise for the work of the contributors who each year in the Reviews produce a relatively small book, unique in its certainty of interest to all professional chemists.—A. S. FREEBORN.

The Electron Microscope, by M. E. Haine, D.SC. (Bristol), M.I.E.E., F.Inst.P. (including a chapter written in collaboration with V. E. Cosslett, M.A.(Oxon.), M.Sc. (London), Ph.D. (Bristol). London: E. & F. N. Spon Ltd., 1961, pp. 282 + xvi, 55s.

This is a simplified introduction in ten chapters to the electron microscope. Chapter 1 deals with the properties of electron lenses. It is admirably illustrated and any necessary mathematics used is simple. Aberrations are compactly reviewed and in all this is a useful simple 20-page survey of what is really a complicated matter. Chapter 2 considers wave propagation and coherence and is likely to be largely skipped by biological electron microscopists; indeed little harm would be done in doing so.

Chapter 4 deals with the formidable problem of image contrast as linked to electron scattering and for simplicity the mathematical treatment here is largely a matter of quoting formulae laboriously arrived at elsewhere.

From Chapter 5 onwards we come to practical operations, and resolution, stability and testing methods are reviewed. Chapter 6 is devoted to the electron gun. While this is, of course, important in the instrument design, most users of the electron microscope will be apt to take for granted this part of the equipment. This is a chapter likely to interest only those engaged in the *production* of electron microscopes and as the author is director of research at an A.E.I. laboratory this especial interest is to be expected. Chapter 7 briefly reviews methods of recording the image.

In treating of instrument design the features described are those mainly of the Metropolitan Vickers E.M.6. This restriction to one kind of instrument is a severe drawback in treatment. This is after all not a brochure for the E.M.6 but a text-book, and such a narrow restriction to the product of *one* manufacturer is to be deplored. This is the largest chapter in the book (57 pages) and the absence of reference to any of the other admirable instruments available creates an unfortunate impression. If a second edition is to be called for (the book deserves this) it is to be hoped that an equally large chapter will be added describing other electron microscopes, especially in so far as they differ from the E.M.6.

Chapter 9 contains a brief, indeed rather superficial, review of electron reflection, electron diffraction, electron probes and scanning techniques and only a mention of such things as the point-emission microscope. It offers virtually no help to the reader.

Chapter 10 on specimen techniques (in collaboration with Dr. Cosslett) will be read eagerly by all practical electron microscopists. It is packed tight with valuable 'know-how' and admirably illustrated.

Apart from the genuine weakness of restriction to only a single type of microscope, this is a good practical and well illustrated book, and we welcome its appearance. The price is rather fierce, an unfortunate current tendency.—S. TOLANSKY.

Natural Gas and Methane Sources, by James Lawrie. London: Chapman & Hall, 1961. pp. 204 + xiv. 35s.

The production of natural gas is expanding rapidly and it is becoming an increasing factor in the total energy markets of the world. This is being facilitated by improvements in its distribution either as a gas by pipeline or as a liquid by tanker. Other sources of methane are available from coal mines, bacterial decomposition of sewage or farm wastes and it can also be separated from coal treating and oil cracking processes. With the increasing availability of methane it is also being used more extensively for the production of chemicals such as ammonia, urea, methanol, acetylene and carbon black. It is therefore timely that a book should be produced surveying the whole of this field and bringing together the latest information on the subject. It is an entirely newly written book and is not a revision of Dr. Lawrie's 'Methane, Its Production & Uses' published in 1940.

It is a pity, therefore, that the present volume suffers from a rather scrappy presentation and a lot of minor inaccuracies. The part of the book dealing with the production of methane by mine drainage is good but some of the information on natural gas is not well set out and, moreover, the use of different units leads to confusion. For example, on page ten the estimated known world reserves of natural gas are given as 20,000 million M^3 excluding the recent discoveries in the Sahara and Mexico but the 1957 marketed production in the U.S.A. alone is given as 10,680 billion cu. ft. (p. 40). Assuming the American billion is used (10^9) one year's production appears to be greater than the known reserves. Similarly Alberta in 1956 is stated to have recovered 146,133,713 million cu. ft. of gas but the 1956 reserves were only 18,300 billion cu. ft. (p. 43).

Chapter 6 gives the natural gas position in the different countries of the world but Iraq and Persia are dismissed briefly as having fertiliser plants based on natural gas but no mention is made of their large gas reserves, although reference is made later in the book to the Bechtel scheme for large-scale transmission of natural gas by pipeline from Iraq across Europe. No mention is made of Pakistan which has a large gas field (Sui).

In dealing with towns gas the author takes a very parochial view when he states that if methane is used in towns gas it is necessary to reform it to reduce the calorific value. Natural gas is used without reforming or dilution in the U.S.A.

The author has used a new unit of pressure, kg./cu.m. (p. 98) and in France gas is apparently purchased by the square metre (p. 184) but the chemistry has suffered most—urea is given as $CO(NH_3)_2$ (p. 162), water and CO_2 apparently react to give methane and water (p. 72), while atomic hydrogen turns up on p. 8 and p.73. This is obviously due to inadequate proof reading which is already apparent from the frontispiece and list of illustrations which refer to 'La Plaz' field instead of 'La Paz'. It is to be hoped that these and other errors will be corrected in any new edition.—M. A. MATTHEWS.

THE McFADZEAN LABORATORY

THE McFadzean Laboratory, named after the Chairman of British Insulated Callender's Cables Ltd., is the latest addition to the Group's research facilities.

The scientific and engineering forces are subdivided into two main groupings—engineering and research. The engineering group has laboratories located in every production unit and the primary responsibilities of these laboratories are to exercise quality control in its broadest sense, to improve existing products, whether it be in the materials or the plant and processes which are used, to develop new products to the stage of final production, and to maintain the necessary technical contacts with customers and others.

The Research Organization, which is concentrated in the Wood Lane laboratories, is responsible for carrying out such long-range experimental work as is necessary to feed to the engineering laboratories the information which they need to fulfil their shorter-range objectives, and to conduct basic research in fields of lasting interest, regardless of immediate applicability. In addition, the Research Organization provides central facilities in those cases where they are required by several factories but which demand such specialized personnel or equipment that a number of separate laboratories would be uneconomic or inefficient. The Organization has ten experimental departments, each working in a well-defined field of science or technology, and four of these are housed in the new building; the others are in other buildings on the site. All these departments are supported by a works engineering group with its comprehensive workshops and machine shops.

The McFadzean Laboratory is a six-storey building providing 64,000 sq. ft. of floor space and accommodates the Instrumentation and Control Department, the Physics Department, British Dielectric Research Limited (a Group subsidiary for research on capacitors), the Diffraction and Microscopy Department and, in addition, the electronic computer which is an important part of the facilities of the Mathematics Department, the main offices of which are elsewhere. Also, the laboratory contains the drawing office, the photographic section, the main conference room, a lecture room, some administration offices and catering and social facilities.

These departments were selected as those which most need the atmospheric conditions provided by the complete air-conditioning of the new building but which do not need extensive provision for chemical research (which is carried out in other buildings). However, to permit limited chemical or physico-chemical work, the east wing of the building is equipped with chemical drainage and fumes extraction.

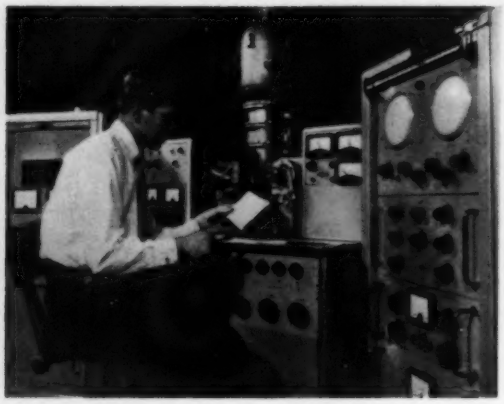
The laboratory has a complete basement which, besides having accommodation for the storage of records, the electrical sub-station, refrigeration and space-heating plant and the automatic telephone equipment, provides a large space to be used for life-testing and similar long-term tests which need only occasional supervision.

The ground floor contains the entrance vestibule and the conference room but is otherwise wholly occupied by the Instrumentation and Control Department. This department is one of those which provides a centralized service to the Group and is responsible for:

(*a*) developing novel measuring devices, mainly for use in the factories in non-destructive quality control testing;
(*b*) designing and constructing complete schemes of instrumentation, using either specially developed or conventional equipment;
(*c*) devising automatic production equipment to replace and improve upon existing manual control methods, to improve product quality or to economize in material usage.

The Physics Department occupies the whole of the first floor and nearly all of its work is of a long-range nature and largely concerned with the dielectrics used for power cables of all descriptions. The most important topic, and one in which studies have been in progress for very many years, is research into the properties of dielectrics for very high voltage cables and the department is very well equipped for this purpose. With oil-impregnated paper dielectrics, for example, studies commence with the manufacture in the laboratory of the paper itself, which can then be tested in a

General view of the electronics laboratory.



The X-ray scanning micro-analyser.

range of instruments, some specially designed for the purpose, before being built up into cable models in which it is possible to reproduce all the conditions to which a full-size cable will be exposed during its manufacture and service life. Of necessity, the department has its own high voltage testing equipment which is normally of adequate range but, if higher voltages or currents are needed, the larger facilities of the main High Voltage Department are available.

There is a growing field of work in the possible use of plastics for high voltage cables but the advances which might still be made in the apparently less glamorous fields of low voltage insulation (rubbers, plastics and minerals, etc.) are not by any means overlooked and research programmes are in progress.

The second floor is devoted to research on capacitor dielectrics, in the hands of British Dielectric Research Limited, which serves both the Capacitor Division of B.I.C.C. and the Telegraph Condenser Company Limited, a B.I.C.C. subsidiary. The department has sections dealing with all types of capacitors—oil-impregnated paper, electrolytic, metallized plastic, ceramic, etc.—and possesses equipment for manufacturing laboratory specimens of all kinds. It also has an extensive range of measuring facilities for the study of initial characteristics and life performance. The work of the department appears at first sight to have certain similarities to that of the Physics Department, with which it collaborates as necessary, but there are actually essential differences between the requirements of capacitor dielectrics and cable dielectrics which account for differences in experimental techniques and methods of attack.

The third floor houses the Drawing Office, the Diffraction and Microscopy Department and the Photographic Section.

The Diffraction and Microscopy Department is concerned mainly with the fine structure of materials and provides an analytical service of this nature to all other departments of the Organization. It has its own research programmes, but these are mainly concerned with improvements in its own techniques. There are three main items of equipment.

The X-ray micro-analyser is an instrument of recent development. The specimen which is being examined is scanned by an electron beam only one-thousandth of a millimetre in diameter. The X-rays which are generated, the wavelengths of which are characteristic of the elements in the surface of the specimen, are analysed and the results displayed either visually on the screen of an oscillograph as an 'X-ray image', or automatically recorded. This enables elements which are present only in minute quantity to be located and identified. The technique is especially valuable in metallurgical studies for the examination of segregates, alloying constituents, etc.

The X-ray diffraction camera is used in the identification of crystalline elements or compounds and for the determination of crystal orientation and texture. The techniques are all well established but the instrument remains one of the most versatile of laboratory tools.

Lastly, the electron microscope has such resolution that it permits magnifications much higher than are possible with the optical microscope and it has, in addition, such depth of focus that stereo-techniques are readily applicable so that photographs may be produced in three-dimensional form.

The Photographic Section has many duties of a routine nature but it is also an essential part of the scientific facilities of the laboratories. Its extensive equipment includes high-speed cinematography, and photographic methods are frequently used for measurement purposes.

The only laboratory on the fourth floor is that containing the electronic computer, which is used for mathematical and engineering design problems. The computer is particularly useful for the latter, because it has a much larger store than is usually needed for strictly mathematical purposes. One application which is readily understood and demonstrated is the calculation of the control requirements for installing heavy submarine power cables in deep water.

Other large projects which are in hand include the complex problem of designing minimum-cost overhead power line towers, and the calculation of the sag/tension data required in overhead line installation.

The remainder of the fourth floor contains the kitchen, cafeteria and lecture room.

The fifth floor is devoted mainly to staff amenities, whilst the partial sixth floor is used only for plant rooms for the ventilation and mechanical services.

The whole building may rightly be claimed to be convincing evidence of the high priority given by B.I.C.C. to research as a means of ensuring the progressive development of its vast range of products in the service of the electrical engineering industry, at home and abroad.

LABORATORY EQUIPMENT & APPLIANCES

Ion Exchange Techniques

Two English chemists, as far back as 1935, produced the first of the modern synthetic ion exchange resins. Due to a variety of reasons, not the least of which was the war of 1939-1945, the major development in this field took place in the United States.

At the end of hostilities, it became evident to Mr. Ward, President of Crystal Research Laboratories Inc. of Hartford, Connecticut, U.S.A., that ion exchange techniques could find a wide application in the laboratory, pharmaceutical and similar fields. It also became obvious to him that the normal method of application by column operation with regeneration *in situ* was not appropriate to those applications where small quantities of water were required and regeneration facilities were not easily obtainable.

The obvious expedient of employing a cartridge made of translucent or transparent material such as polythene, attached to a convenient receptacle for holding raw water was adapted for a variety of purposes which extended not only to cover laboratory and scientific fields in general but also into the realm of home application such as the topping up of electrical batteries and the feeding of steam irons and the like. The use of these simple devices has grown over the years in the United States and at the present time very large numbers of small de-ionizers, working on the principle of a polythene bottle attached to a cartridge, are sold.

The Crystalab Deeminizer.

A newly formed subsidiary of Crystal Research Laboratories Inc.—Crystalab Ltd.—is now in a position to offer the complete range of Crystalab equipment to the British market.

For laboratory purposes the Deeminac is available. These vary in size between units capable of giving 2½ gal. of treated water per cartridge to larger cartridges giving 9 gal. These figures are based on water of medium 'hardness' containing up to 140 p.p.m. dissolved solids (as calcium carbonate). Appreciating that the major cost of ion exchange equipment lies in the indicating means determining whether the water is suitable for use, the smaller units employ a colour indicator in the anion exchanger which gives positive indication of exhaustion by colour change. Since flow rate largely determines the purity of the water discharged through these cartridges and since exhaustion is progressive and therefore the observation of colour change is important, the smaller laboratory units are supplied with a stand so that the discharged water passes through the unit at a predetermined rate, gives an effluent which falls within the B.P. specification for purified water. Apart from the application of purifying tap water, units of this description find ready means of treating ordinary distilled water which may not be of sufficiently high purity for analytical purposes. In this case the bottles can take the place of the ordinary wash bottle. Cartridge life under these circumstances is very protracted.

The Deeminizer is a moderately priced, gravity fed, deionizer which incorporates a simple but efficient electrical means of indicating the quality of the water passed through the unit. Two alternative reservoirs are offered: either the reservoir supplied with the unit or the reservoir plus an ordinary 1 gal. capacity jug of the 'Squash' type which can be fitted to the top of the unit. For the sake of convenience the electrical indicating device is graduated in parts per million as sodium chloride but naturally this can easily be converted to any other scale required. It is mains operated and wound for 200-240 volt a.c. 50 cycle supply. As in the case of all Crystalab units the ion exchange resin cartridges are easily replaceable.

Realizing the need of a simple indicating device for monitoring the purity of distilled or deionized water Crystalab also offer the instrument alone so that it may be employed in any desired way.

For those applications where larger supplies are required with raw water feed directly from the mains at reasonably high flow rates a special ion exchange unit working as the upward displacement method is offered in the Deemajet. This consists of a container filled with ion exchange resin containing a colour indicator, the water being fed in at the bottom and being dispersed across the whole area of the cartridge by means of a porous membrane. The colour indication is similar to that mentioned earlier. Regeneration facilities exist so that, where appropriate, the cartridges may be returned for regeneration. In addition facilities are offered for the regeneration of special resins where specific applications other than water deionization are required.

(Available from: Crystalab Ltd., Dell House Laboratory, Chalfont St. Giles, Bucks.)

New Ultragraph Recorder

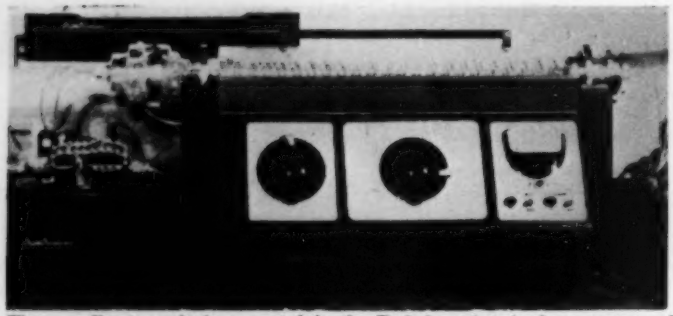
Direct recording of high speed physical phenomena within the frequency range of d.c. to 5,000 c/s. is possible with the new ultragraph from the ABEM Company of Stockholm.

Up to 14 independent channels are available for recording stress, strain, vibration, oscillation, displacement, pressure and temperature changes, or other related events capable of conversion to electrical voltage.

Designed for use in research and industry, the instrument incorporates ultra sensitive galvanometers, measuring only 75 mm. by 6·5 mm. in diameter which dispense with the need for intermediate amplifiers for many applications.

The Ultragraph employs a high pressure mercury vapour lamp, and recordings are made on u/v. sensitive paper; no processing is required and the traces print out almost immediately.

(Sole Distributors in U.K., U.S.A., the Commonwealth and certain European territories: Smiths Industrial Division, Kelvin House, Wembley Park Drive, Wembley, Middlesex.)



The new digestor unit incorporated in the Technicon AutoAnalyzer system of continuous automatic chemical analysis.

New Digestor Unit

The introduction into the AutoAnalyzer, an instrumental system of continuous automatic chemical analysis, of a continuous digestor unit has recently been announced. This permits automatic analysis of nitrogenous compounds with a degree of reliability and reproducibility unobtainable by conventional methods.

The new instrumental system, applicable to both reductive and oxidative types of digestion, completely eliminates the traditional stumbling block to automating Kjeldahls and similar digestion-requiring procedures. No longer is it necessary to provide for a suitable time lag to enable such phases of the process as reduction and oxidation to occur. Additionally, it eliminates the need for isolating each phase in the digestive procedure, from the previous phase and from newly-introduced sample material just beginning the digestive process. Equally important is the fact that it handles the work with equipment occupying but a fraction of the space required for conventional methods.

Integrated with the AutoAnalyzer, the new unit not only fully digests the material it is fed but provides for quantitation and permanently records results on a graphed readout. The multiple proportioning pumps in the AutoAnalyzer are used continuously to supply digestion mixtures to the digestor, to present the sample continuously or intermittently and, in the final stages, to remove an aliquot of the digested product for final mensuration and recording.

The digestor vessel is a glass Pyrex tube with helical indentations. It has an overall length of 31 in. and a diameter of 2 in. By rotation of the tube, liquid introduced at one extremity is conveyed in individual puddles or segments to the other extremity. Both extremities of the tube are slightly tapered to prevent condensed moisture from dropping off the end of the tube.

The entire unit is fitted within a hemispherical type furnace where variable-speed rotation is achieved through wheels driven by a variable geared motor. The method permits adjustment of the speed of rotation and thus of the duration of the digestion phase. The faster the tube is rotated, the shorter the time allotted to the digestion of the specimen. An electronic-type temperature control and indicator permits heat adjustment from room temperature to approximately 700°C., an important additional factor in providing a control method for the length of the digestion period.

On emergence from the digestion vessel, the excess fluid is removed and sent to waste, fumes and water vapour are aspirated and exhausted, and the highly concentrated digestion is diluted, cooled and aspirated.

In the final step, the fully digested and prepared material is introduced into the AutoAnalyzer for analysis and permanent recording of the results on a graphed readout. The entire process is automatic with no human manipulation required.

(Manufacturers: Technicon Instruments Co., Ltd., 26 Warwick Road, London, S.W.5.)

Display Oscilloscope

A new oscilloscope has been introduced which is designed for use primarily as an instructional and demonstration instrument for displaying low frequency (0 to 10 k/cs.) waveforms. A 17 in. cathode ray tube is fitted, having a brilliant orange trace with a long afterglow effective up to approximately 30 seconds in normal room lighting. The full area of the screen is usable and the display is clearly visible from the greatest distances normally encountered in classrooms.

The instrument consists basically of the CRT and its controls, together with X and Y amplifiers having input terminals on the front panel. Two additional units, a time base generator and a beam switch unit, are built in and feed the X and Y amplifiers through quick-release links between the front panel terminals.

The time base generator provides sweep speeds continuously variable from one second to one millisecond and is synchronized internally from the Y1 input channel in the beam switch unit.

The beam switch unit incorporates four Y pre-amplifiers, each with its own gain and shift controls and a coaxial input terminal on the front panel. It may be set to give a 1, 2, or 4-trace display, enabling up to four related waveforms to be shown on the screen at once.

The instrument is normally used with its own time base generator in operation, but this may be quickly disconnected by removing the front panel links. External signals may then be applied directly to the X amplifier for generating Lissajous figures, and if required four such figures may be displayed at once by using the beam switch unit.

Although designed principally for instructional use the instrument has proved valuable for low frequency applications in general laboratory work, where its large brilliant display confers advantages in ease and convenience of operation.

The display oscilloscope Type 279 is described fully in Descriptive Leaflet No. 215, available on request.

(Manufacturers: Airmec Ltd., High Wycombe, Bucks.)

Sigrist Photometer

The Sigrist photometer UP2/LD is a new combined absorptiometer and nephelometer for laboratory use. It uses the fully automatic optical compensation method unique to Sigrist photometers whereby all measurements made are a function only of the structure of the light path, being independent of instrumental variations such as light source, photocell sensitivity and amplifier gain.

Various versions are available, with or without inkless recorder and motor-driven monochromator.

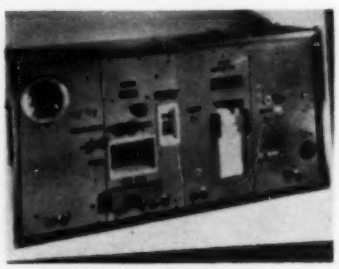
Absorption range:

with filters	366-950 mμ
with Monochromator	400-1000mμ

Turbidity range:

2×10^{-5}-6×10^{-2} absolute units.

(Distributors: Southern Analytical Ltd., Frimley Road, Camberley, Surrey.)



The Sigrist photometer is a new combined absorptiometer and nephelometer for laboratory use.

New low cost proportional controller by Honeywell, the Pyr-O-Volt, for controlling electrical loads with magnetic amplifier and saturable core reactor.

Low Cost Proportional Controller

For stepless proportional control of electrical loads using magnetic amplifier and saturable reactor, a new millivoltmeter instrument known as the Pyr-O-Volt has been developed.

The Pyr-O-Volt controller 105R12 is an inexpensive current-proportioning instrument with no contactors. It has a continuous output of 3 to 7 milliamps working into an impedance of 4,000 ohms or more when used as the input to a magnetic amplifier. It will control saturable core reactors up to 100 kVA., with provision for control of larger reactors.

Among important features are the straight line control, automatic fail-safe, built-in voltage regulation, plug-in design, adjustments on the instrument itself, connection and servicing from the front.

In the same family is another new instrument, the millivoltmeter indicator 105X11, which has a high quality moving coil movement and a plug-in design.

These instruments are likely to find application in metal producing and processing, ceramics, plastics extrusion, and other industries. They could also be used in research.

(Manufacturers: Honeywell Controls Ltd., Greenford, Middlesex.)

Storage Unit

Designed for the storage of small fragile containers, bottles and capsules, a new 14 drawer unit has been added to the standard range of Raaco industrial cabinets. This new unit is 7⅞ in. high × 12¼ in. wide × 5¼ in. deep and has been specially designed for laboratory or shop counter use. By using sub-dividers, this small unit provides for 54 separate compartments.

The new 14-drawer Raaco unit with 54 separate compartments.

The drawers are contained in a sheet metal cabinet with a grey hammer finish, and the cabinet itself can be stacked or fastened to the wall. Apart from its versatility for use on individual bench units, extensive compact storage installations can be assembled with larger-sized Raaco units, all standardized on width and depth.

(Manufacturers: James H. Randall & Son Ltd., Paddington Green Works, London, W.2).

A Slow Neutron Detector

A new slow neutron detector NE 421 of Li^6F is now available. The new detector makes use of the fact that the alpha particle emitted from Lithium 6 after neutron capture has a higher energy than the corresponding alpha from Boron 10, and this leads to considerably higher detection efficiencies in the scintillator.

(Manufacturers: Nuclear Enterprises (G.B.) Ltd., Bankhead Medway, Edinburgh, 11.)

The Flatters & Garnett No. 1 Microprojector as shown at the recent Laboratory Apparatus and Materials Exhibition.

NEWS

General

New Research Laboratories at Lathom

The new laboratories built by Pilkington Brothers Limited at Lathom, near Ormskirk, Lancashire at a cost of £2 million, form the largest glass research centre in the world and what is also thought to be the biggest single research unit of any kind in Britain.

Situated in a site covering 160 acres the laboratories will eventually accommodate a total of 500 people of which 150 will be graduates.

The scientific and technical staff will undertake basic and applied research on products of the whole Pilkington Group, which will include flat glass, optical glass, glass fibres, insulators and cathode ray tubes. This work involves studies in solid state physics, organic and physical chemistry, metallurgy, statistics, electronics, x-ray techniques and other subjects.

Three main types of building have been provided to suit the scale of work to be done: the first for small scale, the second for medium scale and the third for large scale experiments. Other buildings include a radio-chemical laboratory, workshops, stores, a lecture theatre and a canteen. The total floor area of the buildings is just over 250,000 sq. ft.

The small scale laboratory is a four-storey building 450 ft. long, 65 ft. wide and is constructed from precast concrete units. All windows are double glazed and Muroglass cladding is used extensively. The design is modular giving bays measuring 13 ft. 4 in. by 26 ft. 8 in. and 11 ft. high. Most laboratories are made up of two or three bays but some are as large as five bays.

Each bay if provided with six service outlets in the floor distributed so that it is possible to have electricity, gas, water and drainage available within six feet of any working space in the building.

The medium scale laboratory with a floor area of about 39,000 sq. ft. and a height of 20 ft. is a single storey steel frame building with large open working areas.

The large scale research laboratory is 450 ft. long, 80 ft. wide and 40 ft. high. It is a steel portal frame building clad with asbestos sheets and vertical patent glazing and provides extensive open working space for large scale experiments.

The laboratory for radiochemical work is at present under construction and is a separate building of 5,500 sq. ft. incorporating the most modern ideas in this field. It is designed not only for the study of the effects of radiation on glasses, but also for the application of the powerful techniques now available with the use of radioactive materials.

All the laboratory benches in the administration and laboratory building of Sandoz Products Ltd. are topped with grey Warerite. The centre islands, which carry electricity, gas and compressed air supplies, are faced and topped with the same materials.

A general view of the interior of the medium scale research laboratory of Pilkington Brothers new £2,000,000 glass research centre at]Lathom, near St. Helens. It has a floor area of about 38,000 sq. ft., with a headroom of about 20 ft.

Yorkshire Laboratories

The large laboratories of the Administration and Laboratory Building of Sandoz Products Ltd., Horsforth, Leeds, are one of the most recent users of Warerite laminated plastics which is impervious to staining, greases, organic alkalis and weak acids. It is also heat resistant and unaffected by extreme cold: all qualities which render it ideal for laboratory bench tops and other uses. From a staff point of view, the ease with which Warerite can be wiped clean with a damp cloth is, perhaps, a most important attribute.

Over 300 sheets of grey Warerite have been used for bench tops, and the tops and sides of bench supplies 'stands'. In the dyestuffs samples rooms, stepped shelves of Warerite grey have been fabricated; a system that allows small bottles to be stored in glass-fronted cabinets in positions which allow all the labels to be read at a glance, and any particular sample identified immediately. Here, again, Warerite enables thorough cleaning to be undertaken with a minimum of effort.

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Other materials when necessary

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Six capacity ranges
Smallest from zero to 100 ccs./hr., largest from zero to 1,500ccs./hr. controlled by micrometer adjustment.

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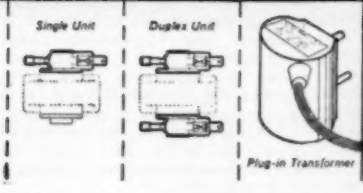

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EXHIBITION LECTURES

It is hoped to include in the August and September issues of LABORATORY PRACTICE the lectures delivered at the recent Laboratory Apparatus and Materials Exhibition sponsored by this journal and staged by U.T.P. Exhibitions Ltd.

Manufacturer's News

Optical Instruments

Hilger & Watts Ltd. are pleased to announce that Wray (Optical Works) Ltd. have come into association with them, and feel that thereby the optical instrument industry of this country will be strengthened.

Mr. A. W. Smith (a former President of S.I.M.A.) is continuing as Managing Director of Wray (Optical Works) Ltd. Mr. Smith is currently Chairman of the S.I.M.A. Education Committee and of the City and Guilds Advisory Committee for Instrument Making.

Personal

Mr. J. W. Ryde

The General Electric Company Limited announces with great regret the death at the age of 63, of John Walter Ryde, F.Inst.P., F.R.S., the Chief Scientist of the Hirst Research Centre of the Company, Wembley, Middlesex.

Ryde was educated at St. Paul's School and the City and Guilds Technical College, Finsbury, where he studied under Prof. Sylvanus Thompson, and subsequently served with the Royal Engineers in World War I. He joined the newly established Research Laboratories of The General Electric Company Limited in 1919, directly from his war service, as a physicist, and was a leading member of the scientific staff of the Laboratories from the start.

His many and varied early research studies included pure spectroscopy, the gaseous electrical discharge and thermionics. His work on the scattering of light, first applied in the '20s to optical diffusing media in glasses, was developed by him during World War II to classic studies of the attenuation and the radar echoes produced by meteorological phenomena at centimetre wavelengths. He made significant contributions to the development of electrical discharge lamps, luminescent materials and optical projection systems. His researches in World War II included velocity modulation tubes and crystal valves for microwave mixer devices, together with work on the FIDO fog dispersal system. The design, in his leisure hours, of a pocket Illumination Chart for Service use was typical of him. It showed levels of illumination, by day and by night at various latitudes, and was used extensively in military operations.

Ryde was elected a Fellow of the Royal Society in 1948, 'distinguished in his contributions to pure and applied physics'. He was appointed Chief Physicist at the G.E.C. Research Laboratories in 1950 and Chief Scientist in 1953. During these recent years he has had overall responsibility for the programmes of pure scientific research of the establishment with particular interests in the fields of new materials, crystal growing and solid state physics.

Mr. Graham Miller

The Wayne Kerr Laboratories Ltd. have appointed Mr. Graham Miller Home Sales Manager responsible to General Sales Manager Mr. Gordon Ball for the sales of all Wayne Kerr instruments in Great Britain.

Mr. Miller studied electronics at Manchester College of Technology and was a graduate in Physics at Swansea University. He subsequently became a circuit design engineer and spent two years as Head of the Ferranti Standards Laboratory at their Wythenshawe Laboratories.

Mr. Miller joined Wayne Kerr two years ago as Sales Engineer for the North of England.

CATALOGUES, BROCHURES & LEAFLETS

Received from Manufacturers

Moisture Determination.—British Drug Houses Ltd., of Poole, Dorset, have issued a second edition of Moisture Determination by the Karl Fischer Reagent. Copies can be obtained direct from the publishers.

Portable and Side-Entry Mixers.—Three new specification leaflets have been issued by Premier Colloid Mills Ltd. of Hersham Trading Estate, Walton-on-Thames, Surrey. One describes the company's portable mixers, another the side-entry mixers and the third gives details of the action and properties of the Dispersator mixing head.

Metabolic Pathways.—L. Light & Co. Ltd., of Colnbrook, Bucks, have published a note entitled Maps and Metabolism written by D. E. Nicholson to be used in conjunction with their metabolic pathways chart.

M. & B. Laboratory Bulletin.—The May 1961 issue of this publication issued by May & Baker Ltd., Dagenham, Essex, contains the following articles: A Biochemical Approach to World Nutrition, High Speed Photography and Micrography, and Kekule and the Structure of Benzine.

Review.—Under this title the Loughborough Glass Co., Ltd. of Loughborough have published the first of a two monthly bulletin giving details of new products and other items of interest.

Gas Liquid Chromatography.—Primarily intended as a comprehensive brochure to describe the new version of the Pye Argon chromatograph, a new 28-page publication issued by W. G. Pye & Co., Ltd., of Granta Works, Cambridge, contains details of many techniques which have recently been developed in the field of chromatographic analysis.

Marconi Instrumentation.—Marconi Instruments Ltd. of St. Albans, Herts., have adopted a new format for their monthly publication, the chief change being in the alteration of the page size and the introduction of a semi-stiff cover. The main technical content of the bulletin remains unchanged and this present issue contains details of a wide range, R-C oscillator, two special bridges, white noise test set, standardization of F.M. deviation meters and a F.M. signal generator.

Dissolved Oxygen Analysing Meter.—The Cambridge Instrument Co., Ltd., 13 Grosvenor Place, London, S.W.1. have produced a new publication describing their physical type dissolved oxygen analysing meter. This instrument provides a continuous automatic analysis of boiler feed water in smaller power producing plants employing mechanical deaerators. The equipment described is not suitable where chemicals are added to the feed water and the company's electrochemical analyser is mentioned as being suitable for these conditions.

Scientific and Laboratory Glassware.—A greatly improved 76-page catalogue of Pyrex scientific and laboratory glassware, tubing and rod has been published by the manufacturers, James A. Jobling and Co., Ltd., Wear Glass Works, Sunderland. It gives descriptions and dimensions of more than 750 items in the standard range, with notes on the chemical and physical properties of Pyrex glass. Features which make the catalogue easy to use are division by application into 10 sections, clearly shown in the list of contents, a comprehensive, cross-referenced index, and a simplified line drawing of each type of apparatus against its catalogue entry. The catalogue is not bulky, is easy to file and its pages lie flat when opened. The inside back cover contains a pocket for current price lists.

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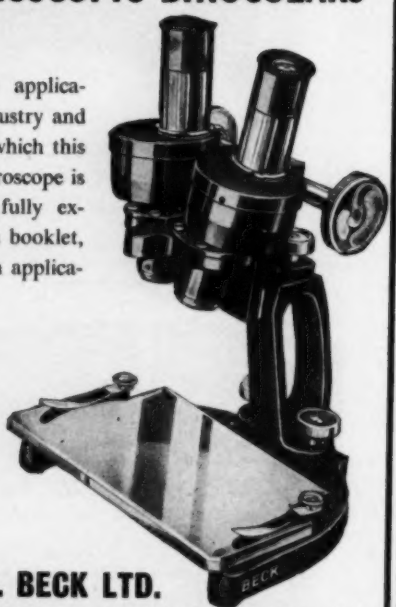

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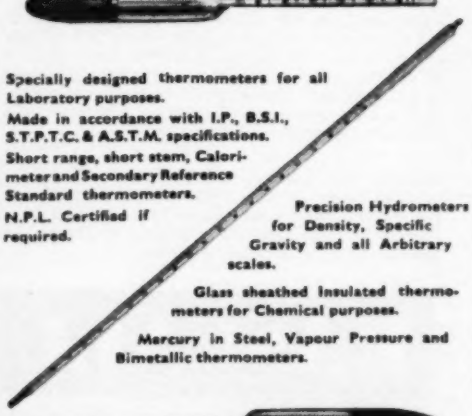

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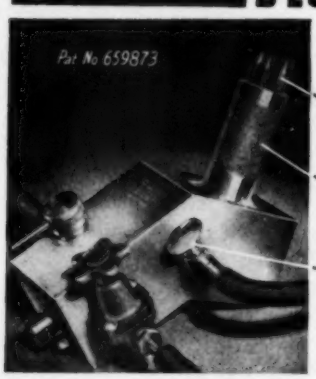

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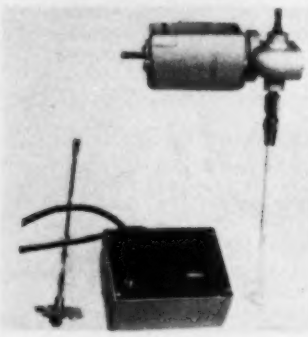

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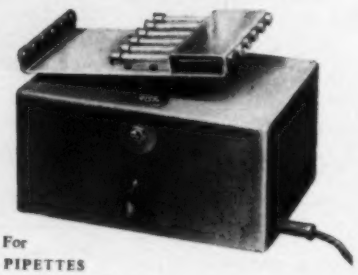

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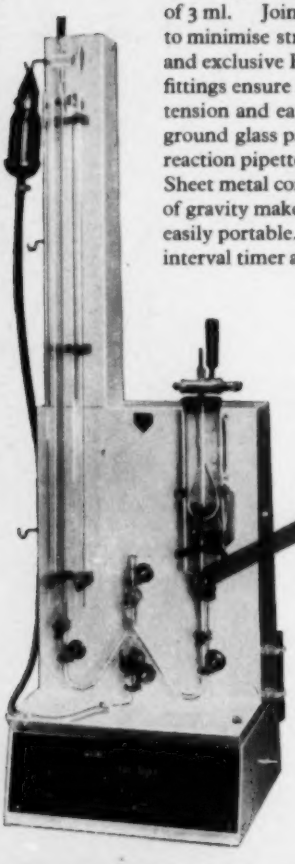

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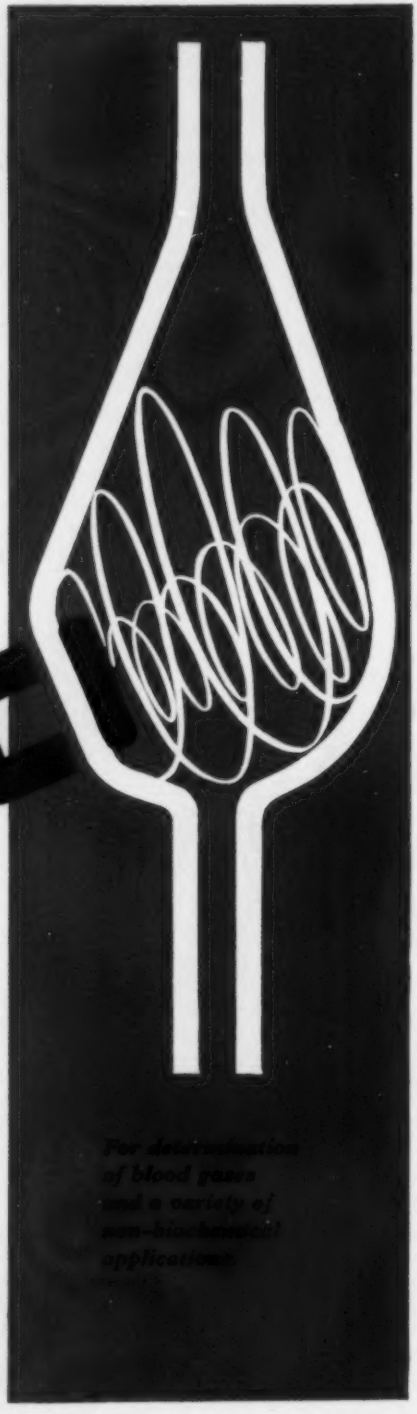

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